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## Influence of ergometer design on physiological responses during rowing

**J. Rossi, E. Piponnier, L. Vincent, P. Samozino, L. Messonnier**

Journal:	<i>International Journal of Sports Medicine</i>
Manuscript ID:	IJSM-09-2014-4455-tt.R2
Manuscript Type:	Training & Testing
Key word:	oxygen uptake, lactate , rowing efficiency, submaximal exercise
Abstract:	<p>The aim of this study was to compare the physiological responses and rowing efficiency on two different rowing ergometers: the Concept2 stationary versus dynamic ergometers. Eleven oarswomen and oarsmen rowed four minutes at 60% and 70% of peak power output on both ergometers (randomized order). Power output, stroke rate, heart rate, oxygen uptake, carbon dioxide production, lactate accumulation and rating of perceived exertion were recorded at each stage on the two ergometers. Gross and net efficiencies were computed. Exercise intensity was associated with increases in all parameters. Rowing on dynamic ergometer was associated with higher heart rate, oxygen uptake, carbon dioxide production and stroke rate, concomitantly to lower blood lactate accumulation but also lower gross and net efficiencies. The present study showed that rowing efficiency and blood lactate accumulation were lower on the Concept2 dynamic ergometer than on its stationary counterpart. If the use of the Concept2 dynamic ergometer may provide some advantages (reduced risk of injuries), its utilisation requires specific evaluation of physiological responses during an incremental exercise for an adapted management of training.</p>

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TITLE PAGE

For Peer Review

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3 25 **ABSTRACT**  
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5 26 The aim of this study was to compare the physiological responses and rowing efficiency on two  
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7 27 different rowing ergometers: the Concept2 stationary versus dynamic ergometers. Eleven  
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13 30 dioxide production, lactate accumulation and rating of perceived exertion were recorded at each  
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15 31 stage on the two ergometers. Gross and net efficiencies were computed. Exercise intensity was  
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17 32 associated with increases in all parameters. Rowing on dynamic ergometer was associated with  
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19 33 higher heart rate, oxygen uptake, carbon dioxide production and stroke rate, concomitantly to  
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21 34 lower blood lactate accumulation but also lower gross and net efficiencies. The present study  
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25 36 dynamic ergometer than on its stationary counterpart. If the use of the Concept2 dynamic  
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27 37 ergometer may provide some advantages (reduced risk of injuries), its utilisation requires specific  
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29 38 evaluation of physiological responses during an incremental exercise for an adapted management  
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41 41 Keywords: oxygen uptake, lactate, rowing efficiency, submaximal exercise  
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## 45 INTRODUCTION

46 Rowers extensively use rowing ergometers for training, especially during the winter season.  
47 Ergometers are also used to evaluate the performance level of the rowers and their physiological  
48 characteristics such as maximal oxygen uptake and blood lactate kinetics in response to exercise  
49 which are closely related to rowing performance on water and on ergometer [18,23]. In that  
50 sense, results obtained on ergometers are sometimes used as selection criteria by some rowing  
51 national teams [11]. Although to a lower extent than on water, performance on ergometer is also  
52 related to mechanical efficiency [4,12]. On classic stationary ergometers, previous experiments,  
53 but not all [25], have shown that rowing efficiency increased when exercise power output  
54 augmented [4,9,22]. This increase in rowing efficiency with work rate may at least in part  
55 account for the higher gross efficiency observed in adults than in young rowers since the former  
56 exercised at higher power outputs [22].

57 Dynamic ergometers have been developed in order to mimic more closely on-water rowing  
58 movement and feelings [7]. Contrary to the stationary design where the rower moves forth and  
59 back on the ergometer, the centre of mass of the rower is much less displaced on the dynamic  
60 ergometers where it is the system that moves: foot stretcher and flywheel on RowPerfect or  
61 ergometer as a whole in the case of Concept 2 with slides. Furthermore, the total mass of the  
62 system that moves is lower than the mass of the rower [15]. In that case, the energy spent to move  
63 the body of the rower [6,9] and the system (*vide supra*) back and forth might be lower on the  
64 dynamic ergometers since the inertial forces to develop for each stroke are expected to be lower.  
65 Following this line of reasoning, rowing efficiency can be expected to be higher on the dynamic  
66 ergometers. However, and although peak handle forces were also lower on the dynamic  
67 ergometers [1,5,15], the physiological responses to a given exercise intensity have been observed  
68 to be comparable on stationary and dynamic ergometers [15,19], suggesting similar overall

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3 69 energy expenditure and consequently rowing efficiency on the two ergometer designs. Worst,  
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5 70 contrary to this inference, Benson et al. [1] found lower rowing efficiency at maximal pace on  
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7 71 dynamic rowing ergometer than on the stationary. They attributed these alterations in rowing  
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9 72 efficiency to the higher stroke rate on the dynamic ergometer, inducing higher energy  
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11 73 expenditure. They also evoked the low rowing performance level of their subjects. Indeed, these  
12  
13 74 alterations in rowing efficiency have not been observed in oarswomen of higher ranking.  
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15 75 Nevertheless, Holsgaard-Larsen and Jensen [15] also reported a lower economy while rowing on  
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17 76 slides (dynamic condition) than without (stationary) in high-level Danish rowers. They also  
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19 77 attributed this lower efficiency to the higher stroke rate on the dynamic ergometer.  
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24 78 Recently, a new dynamic ergometer appeared (Dynamic, Concept 2, Morrisville, USA). In  
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26 79 that new frame, only the segments of the rower and the stretcher move, so that the masses to  
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28 80 displace are minimised. This could induce a lower internal mechanical work to accelerate the  
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30 81 segments mass at each stroke, which could result in a higher efficiency than on other dynamic  
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32 82 design ergometers. Consequently, it is possible that the difference in rowing efficiency between  
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34 83 the brand-new dynamic and other stationary ergometers does not exist anymore, despite still a  
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36 84 higher stroke rate on the former device.  
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41 85 Thus, the aim of this study was to compare the physiological responses and rowing  
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43 86 efficiency on two different rowing ergometers: the Concept2 stationary (model D) versus  
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45 87 dynamic ergometers. Specifically, we hypothesized that the higher energy expenditure related to  
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47 88 stroke rate would be compensated by a low energy expenditure related to the masses to displace,  
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49 89 so that rowing efficiency would be similar on the dynamic and stationary Concept 2 rowing  
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51 90 ergometers.  
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## 92 **METHODS**

### 93 **Study population**

94 Eleven competitive rowers, 6 men and 5 women (age: 20.0±2.6 years, body mass:  
95 71.4±12.5 kg, height: 176±13 cm and body fat: 15.0±5.2 %) participated in this study. The  
96 present study was approved by the local ethics committee (n°: 20145) and was performed in  
97 accordance with the ethical standards of the IJSM [14] Before giving their written consent, the  
98 subjects were fully informed of the objectives, experimental design, all risks, possible  
99 discomforts, and potential benefits of the experiments.

100

### 101 **Ergometers**

102 Two rowing ergometers with different designs were used: a stationary (fixed-foot stretcher)  
103 rowing ergometer (SRE: model D, Concept2, Morrisville, VT, USA; Figure 1a) and a dynamic  
104 (free-floating stretcher) rowing ergometer (DRE: dynamic, Concept2, Morrisville, VT, USA;  
105 Figure 1b). The two rowing ergometers were new at the time of the experiment. They were  
106 equipped with Concept2 Performance Monitor 4 (PM4) calculator (Concept2, Morrisville, VT,  
107 USA), which measures stroke rate ([cycles . m<sup>-1</sup>](#)) and mean power outputs ([W](#)) continuously. [Both](#)  
108 [ergometers were equipped with the same PM4 calculator giving the same power output](#)  
109 [measurements in both conditions. Note that these PM4 calculators are actually used for](#)  
110 [international and national indoor rowing competitions and in many scientific studies \[1,16,17\].](#)  
111 [Subjects were thus able to adjust exercise intensity according to the required power output.](#)

112

### 113 ***Experimental Design***

114 The experiment consisted successively in i) a familiarisation period, ii), an incremental  
115 exercise up to exhaustion, and iii) a standardized submaximal exercise session.

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3 116 *Familiarization period.* All subjects underwent eight of their regular training sessions on  
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5 117 rowing ergometer in the laboratory. Each training session lasted between 40 and 60 min each.  
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7 118 Half of the training session was performed on one of the ergometer and the other half on the other  
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9 119 ergometer. The order between SRE and DRE was randomized. This procedure allowed the  
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11 120 rowers to become accustomed with the environment and the dynamic ergometer.  
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15 121 *Incremental exercise up to exhaustion (session1).* The graded exercise was performed on  
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17 122 SRE. It started at 120 W for the women and 150 W for the men. After 3 min of exercise at this  
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19 123 load, the work rate was increased by 35 W for the women and 50 W for the men every 3 min  
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21 124 thereafter. The exercise was stopped when the subjects were no longer able to sustain the work  
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23 125 rate. This exercise session was performed for determination of maximal heart rate ( $HR_{peak}$ ,  
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25 126 beats/min) and peak power output ( $P_{peak}$ , W) [3].  
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29 127 *Standardized submaximal exercises (session 2).* This session intervened at least 3 days after  
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31 128 the incremental exercise. After 10 min of self conducted light warm-up, rowers performed on  
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33 129 SRE and DRE ergometers three consecutive exercises of 4-min duration each at 50% (to  
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35 130 standardize the end of the warm-up and reach a steady state level for all rowers), 60% and 70% of  
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37 131  $P_{peak}$ , respectively. After a 20-min rest period, rowers performed the same exercise procedure but  
38  
39 132 on the other ergometer. The order of ergometers was randomized between subjects. The  
40  
41 133 participants were asked to adopt their preferred stroke rate during rowing on each ergometer.  
42  
43 134 Drag factor was set on both ergometers at 110 and 130 for women and men, respectively. [These](#)  
44  
45 135 [values of drag factor were i\) those used by the rowers of the present study during their training](#)  
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47 136 [sessions and during indoor rowing competitions, and ii\) in accordance with those](#)  
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49 137 [advocated/recommended \[13\].](#)  
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57 139 **Measurements**  
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3 140 Oxygen uptake ( $\text{VO}_2$ ), carbon dioxide production ( $\text{VCO}_2$ ) and respiratory exchange ratio  
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5 141 ( $\text{VCO}_2/\text{VO}_2$ ) were measured by portable system for pulmonary gas exchange measurements using  
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8 142 a breath-by-breath analysis device (K4 b<sup>2</sup>, Cosmed, Rome, Italy) and averaged over 15 s. These  
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10 143 variables were recorded every 15 s during the last minute of each stage of sessions 1 and 2 and  
11  
12  
13 144 averaged. Heart rate (HR) was recorded continuously (RS800CX, Polar, Finland) during session  
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15 145 1 and 2 while rating of perceived exertion (RPE) was recorded using the 15-point Borg scale (6-  
16  
17 146 20) after each of the two studied intensities (i.e., 60 and 70% of  $\text{P}_{\text{peak}}$ ). Lactate concentration was  
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20 147 measured on capillary blood samples taken from micropunctures performed at the earlobe at the  
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22 148 end of all exercise intensity stages (i.e., 60 and 70 %  $\text{P}_{\text{peak}}$ ) using a Lactate Scout (EKF  
23  
24 149 diagnostics, Barleben, Germany). In that purpose, submaximal exercises were separated by thirty  
25  
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27 150 seconds of rest. Lactate accumulation ( $\Delta[\text{La}]$ ,  $\text{mmol}\cdot\text{l}^{-1}$ ) during stages of the two studied  
28  
29 151 intensities (i.e., 60 and 70% of  $\text{P}_{\text{peak}}$ ) were calculated.  
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152

### 34 153 *Calculations*

35  
36 154 Standard equations were used to estimate the percentages of energy derived from CHO  
37  
38 155 (%CHOox) and lipid (%Lipidox) as well as their absolute oxidation rates (CHOox and Lipidox,  
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40  
41 156 respectively). These calculations take into account a non-protein  $\text{VO}_2$  and  $\text{VCO}_2$  (considering a  
42  
43 157 standard protein oxidation rate leading to urinary nitrogen excretion of  $0.01 \text{ g}\cdot\text{min}^{-1}$ ) and  
44  
45  
46 158 providing a non-protein respiratory quotient (NPRQ) [8,29].  
47

$$48 \quad 49 \quad 159 \quad \text{CHO} = 4.55 \cdot \text{VCO}_2 - 3.21 \cdot \text{VO}_2 - 2.87 \cdot 0.01 \quad (\text{g}\cdot\text{min}^{-1}) \quad (\text{Eq. 1})$$

$$50 \quad 51 \quad 52 \quad 160 \quad \text{Lipid} = 1.67 \cdot \text{VO}_2 - 1.67 \cdot \text{VCO}_2 - 1.92 \cdot 0.01 \quad (\text{g}\cdot\text{min}^{-1}) \quad (\text{Eq. 2})$$

$$53 \quad 54 \quad 55 \quad 161 \quad \text{NPRQ} = [\text{VCO}_2 - (0.01 \cdot 4.89)] / [\text{VO}_2 - (0.01 \cdot 6.04)] \quad (\%) \quad (\text{Eq. 3})$$

56  
57 162 Therefore,  
58  
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$$\%CHO_{ox} = [(NPRQ - 0.707) / 0.293] \cdot 100 \quad (\%) \quad (\text{Eq. 4})$$

$$CHO_{ox} = (\%CHO_{ox} / 100) \cdot VO_2 \cdot 5.05 \quad (\text{kcal} \cdot \text{min}^{-1}) \quad (\text{Eq. 5})$$

$$\%Lipid_{ox} = (100 - \%CHO_{ox}) \quad (\%) \quad (\text{Eq. 6})$$

$$Lipid_{ox} = (\%Lipid_{ox} / 100) \cdot VO_2 \cdot 4.7 \quad (\text{kcal} \cdot \text{min}^{-1}) \quad (\text{Eq. 7})$$

where: 5.05 and 4.7 are the numbers for kilocalories provided from CHO and lipid per liter of consumed oxygen, respectively.

Because lactate accumulation ( $\Delta[La]$ ) was really modest, the “lactic” component in energy supply was neglected [20]. Therefore, metabolic power ( $P_{metab}$ ) during exercise was computed as the sum of  $CHO_{ox}$  and  $Lipid_{ox}$ , divided by 69.78 to obtain results in watts.

### 173 ***Efficiencies***

174 Gross and net efficiencies were calculated as proposed by Gaesser and Brooks [10]:

$$175 \quad GE = P_{mecha} / P_{metab} \quad (1)$$

$$176 \quad NE = P_{mecha} / (P_{metab} - P_{rest}) \quad (2)$$

177 where GE is gross efficiency, NE is net efficiency,  $P_{mecha}$  is actual mechanical power output, and  
178  $P_{rest}$  is resting metabolic power taking into account a resting  $VO_2$  of  $5.0 \text{ ml} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$  [20].

### 180 ***Statistical analysis***

181 Mean values and standard deviations were calculated for each variable. Normal distribution  
182 of the data was checked by the Shapiro-Wilk normality test. A two-way (*Ergometer*  $\times$  *Intensity*)  
183 analysis of variance (ANOVA) with repeated measures was used to determine the effects of  
184 ergometer and intensity on each variable. Significant results were followed by post-hoc

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185 comparisons using Newman-Keuls post-hoc tests. The critical level of significance was set to  
186  $p \leq 0.05$ .  
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## 188 RESULTS

189 A comparison of mean mechanical, physiological, psychological and kinematic variables  
190 recorded during submaximal exercise on SRE and DRE is summarized in table 1.

191

### 192 *Effect of exercise Intensity*

193 The repeated-measures ANOVA showed a significant effect of exercise *Intensity* on power  
194 output ( $F_{(1,10)}=110.808$ ), heart rate ( $F_{(1,10)}=91.605$ ), RPE ( $F_{(1,10)}=54.950$ ), blood lactate  
195 accumulation ( $F_{(1,10)}=5.502$ ),  $VO_2$  ( $F_{(1,10)}=136.859$ ),  $VCO_2$  ( $F_{(1,10)}=204.933$ ), stroke rate  
196 ( $F_{(1,10)}=17.396$ ) (table 1). Gross efficiency ( $F_{(1,10)}=17.046$ ) was on average 5.3% higher at 70%  
197 compared to 60% of  $P_{peak}$  and net efficiency ( $F_{(1,10)}=8.173$ ) was 3.4% lower at 60% than 70% of  
198  $P_{peak}$  (table 1).

199

### 200 *Effect of Ergometer*

201 No difference was observed on power output and RPE between SRE and DRE. On the  
202 contrary, significantly higher heart rates ( $F_{(1,10)}=12.930$ ) (2.5% and 2.5% for 60% and 70%  
203 exercise intensity, respectively) and stroke rates ( $F_{(1,10)}=9.861$ ) were observed on DRE compared  
204 to SRE. Moreover,  $VO_2$  ( $F_{(1,10)}=13.731$ ) and  $VCO_2$  ( $F_{(1,10)}=8.630$ ) were significantly higher (by  
205 5.1% and 4.6%, respectively) on the DRE compared to SRE. Consequently, statistical analysis  
206 showed a significant effect of *Ergometer* on gross efficiency ( $F_{(1,10)}=12.694$ ) which was on  
207 average 5.1% higher on the SRE compared to DRE (Figure 2a) and net efficiency ( $F_{(1,10)}=13.133$ )  
208 which was on average 5.4% higher on the SRE compared to DRE (Figure 2b). However, it is  
209 interesting to note that blood lactate accumulation was significantly lower on DRE than on SRE  
210 ( $F_{(1,10)}=5.734$ ).

211

## 212 **DISCUSSION**

213 The aim of the present study was primarily to compare rowing efficiency on Concept2  
214 stationary and dynamic ergometers. Specifically, we hypothesized that rowing efficiency would  
215 not be different between the two ergometers. Contrary to this hypothesis, rowing efficiency was  
216 significantly lower on the dynamic Concept2 rowing ergometer than on the stationary. Another  
217 unexpected result of the present study was that blood lactate accumulation was lower on the  
218 dynamic ergometer than on the stationary.

### 220 *Effect of exercise intensity*

221 As expected, HR, RPE,  $VO_2$ ,  $VCO_2$ , lactate accumulation and stroke rate were higher at  
222 70% than at 60%  $P_{peak}$ . Gross and net efficiencies were also higher at 70% than at 60%  $P_{peak}$ . This  
223 result is not surprising on the stationary ergometer. Previous experiments, but not all [25], have  
224 shown that rowing efficiency increased when exercise power output augmented [9,12,22]. The  
225 new information concern the dynamic ergometer for which the same evolution pattern is  
226 observed i.e., rowing efficiency is higher at 70% than at 60%  $P_{peak}$ . Interestingly, the increase in  
227 efficiency from 60% to 70%  $P_{peak}$  is of similar magnitude on the stationary and dynamic  
228 ergometers (concerning gross efficiency +5.2% and +4.8% for SRE and DRE, respectively;  
229 concerning net efficiency +4.1% and +3.8% for SRE and DRE, respectively).

### 231 *Effect of ergometer*

232 Contrary to our hypothesis, gross and net rowing efficiencies were still lower on the  
233 dynamic than on the stationary ergometer. In the present study, gross efficiency was 4.7% and  
234 5.2% higher on DRE than on SRE at 60% and 70%  $P_{peak}$ , respectively. Moreover, the difference  
235 between DRE and SRE was not even reduced by the new frame from Concept2. Indeed, Benson

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3 236 et al. [1] found a 5.6% difference in economy at maximal power on Concept2 with and without  
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5 237 slides and Holsgaard-Larsen and Jensen [15] found 4.3% and 2.6% differences in gross efficiency  
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8 238 at 40% and 55% on fixed and free RowPerfect dynamic ergometer. Thus, the reduction of the  
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10 239 displacement of the body centre of mass on the dynamic Concept2 ergometer which should had  
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12 240 reduced the internal mechanical work to accelerate the segments mass at each stroke is not  
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15 241 sufficient to counterbalance the other factors contributing to increase the energy expenditure.  
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17 242 Note that the kinetic mechanical energy require to move the body mass relative to the ergometer  
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19 243 is *a priori* associated with “internal” work since it does not contribute directly to the power  
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21 244 output on rowing ergometers. As a whole, the kinetic internal work seems to have low impact on  
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23 245 the mechanical efficiency, which is in line with the similar gross efficiency reported in  
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25 246 lightweight and heavyweight rowers by Bourdin et al. [3].  
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29 247 As it has been previously reported for other dynamic ergometers [1,5,15], stroke rate was  
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31 248 higher on the dynamic Concept2 than on the stationary ergometer. As Benson et al. [1] and  
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33 249 Holsgaard-Larsen and Jensen [15] did, we could incriminate the higher stroke rate (which  
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35 250 induces an extra energy expenditure for body mass displacement) to explain the lower efficiency  
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37 251 on DRE than on SRE. However, the literature is consistent with the fact that the higher stroke rate  
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39 252 on DRE is counterbalanced by lower peak force development on this type of ergometer [1,5,15],  
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41 253 that should induce a lower energy expenditure and mitigate the negative effect of the higher  
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43 254 stroke rate, but again this does not seem to be the case. Because i) work rate was the same and ii)  
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45 255 stroke rate was higher on the dynamic ergometer, we can speculate that the cycle-averaged  
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47 256 handle force was lower on the DRE. Our results, interpretation and speculation are reminiscent  
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49 257 with the results of Colloud et al. [5] who found, for similar drag factors and stroke rate, lower  
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51 258 handle force and power output on the dynamic ergometer than on the stationary one.  
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3 259 One possible explanation for the consistent higher ergometer rowing efficiency on SRE  
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5 260 may be that the kinetic work required to accelerate the body centre of mass at each stroke is  
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8 261 partly transferred/transformed as external (propulsive) work in the second part of the drive phase.  
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10 262 Consequently, the higher energy expenditure associated with this internal work is partly used to  
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12 263 produce power output, and in turn contribute to increase mechanical efficiency. This advantage,  
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15 264 in addition to a lower stroke rate, may at the end lead to a higher rowing efficiency on the SRE  
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17 265 than on the DRE.

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20 266 An unexpected result of the present study was that blood lactate accumulation was lower on  
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22 267 the DRE than on the SRE. This result was consistent whatever the work rate i.e., 60% or 70%  
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24 268  $P_{\text{peak}}$  (Table 1). At the present time, one can only speculate on the fact that the lower peak force  
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26 269 for a given power output during rowing on DRE than on SRE may preferentially involve  
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28 270 oxidative fibres and metabolism that may induce a lower lactate production and a higher  
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30 271 removal/recycling [2,24,26,27,28]. However, this hypothesis should be taken with caution since  
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32 272 to our knowledge, no studies have investigated to date the effects of changing the couple  
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34 273 force/motion frequency on lactate kinetic parameters i.e., production, exchange and removal.  
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#### 41 275 Effect of drag factor

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43 276 In the present study, the drag factor was set at 110 and 130 for women and men,  
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45 277 respectively. This raises the question of knowing whether the present results and interpretations  
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47 278 would have been different if other drag factors had been used. Kane et al. [16] found very little  
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49 279 effects of the drag factor on physiological aspects of rowing. Only maximal minute ventilation  
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51 280 was affected. More importantly, no physiological responses to rowing were affected by using  
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53 281 different drag factors (i.e., 100 and 150) during submaximal exercises [16], including the  
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3 282 | [intensities used in the present study. So even if the drag factors had been different, it would have](#)  
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5 283 | [been unlikely that the results and conclusions of the present study would have been different.](#)  
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10 285 | ***Consequences for training management [and performance achievement](#)***  
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13 286 | Rowing ergometers are extensively used during training. Results obtained during an  
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15 287 | incremental exercise (mainly VO<sub>2</sub>, HR and lactate curves) are sometimes used to monitor training  
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17 288 | of the athletes (e.g., [21]). If the use of a dynamic rowing ergometer can be advocated because it  
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19 289 | may reflect more closely on-water rowing [7,18] and reduce the risk of injuries [5] compared to a  
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21 290 | stationary one, the present study highlighted that for a given power output, VO<sub>2</sub>, HR and lactate  
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23 291 | accumulation are different while exercising on Concept2 SRE and DRE. Thus, the  
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25 292 | transfer/application of the results obtained on a Concept2 stationary ergometer to a dynamic one  
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27 293 | is not recommended. Specific evaluations of physiological responses to an incremental exercise  
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29 294 | should be performed on a Concept2 DRE to manage training on this ergometer. [Furthermore, the](#)  
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31 295 | [lower rowing efficiency on DRE may potentially alter the ability to sustain an elevated work rate](#)  
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33 296 | [over the race distance, affecting performance on this type of ergometer. However, this hypothesis](#)  
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35 297 | [has never been tested and further studies are necessary to conclude on this point.](#)  
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43 299 | **CONCLUSIONS**  
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45 300 | The present study showed that rowing efficiency and blood lactate accumulation were  
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47 301 | lower on the Concept2 dynamic ergometer than on its stationary counterpart. If the use of the  
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49 302 | Concept2 dynamic ergometer may provide some advantages (reduced risk of injuries), its  
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51 303 | utilisation requires specific evaluation of physiological responses during an incremental exercise  
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53 304 | for a good management of training.  
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3 376 **FIGURE LEGENDS**  
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8 378 **Figure 1:** Diagram of a rower at catch (black) and finish (grey) positions on the stationary **(a)**  
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10 379 and dynamic ergometer **(b)**. It can be observed the greater horizontal displacement of the rower's  
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12 380 center of mass on stationary ergometer.  
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19 383 **Figure 2:** Mean $\pm$ SD of gross **(a)** and net efficiency **(b)** for SRE ( $\square$ ) and DRE ( $\blacksquare$ ) ergometer at  
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21 384 60% and 70%  $P_{\text{peak}}$ . \*: statistical difference between SRE and DRE and between 60% and 70%  
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23 385  $P_{\text{peak}}$  with  $p \leq 0.05$ .  
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Table 1: Effect of exercise *Intensity*, *Ergometer* and their interaction during standardized submaximal exercise on SRE and DRE.

	60%		70%		<i>Intensity</i>	<i>Ergometer</i>	Crossed
	SRE	DRE	SRE	DRE			
<i>N</i>	11	11	11	11			
<i>Mechanical, physiological and psychological data</i>							
Power (W)	176.4±44.8	176.8±44.5	206.0±53.2	206.8±53.8	p<0.05	NS	NS
Heart rate (beats/min)	163±14	168±12	171±14	176±12	p<0.05	p<0.001	NS
RPE (6-20)	11±2	11±2	13±2	13±2	p<0.05	NS	NS
Δ[La] (mmol.l <sup>-1</sup> )	0.77±0.39	0.63±0.36	1.28±0.83	1.09±0.67	p<0.05	p<0.05	NS
VO <sub>2</sub> (l.min <sup>-1</sup> )	3,35±0,84	3,51±0,84	3,65±0,82	3,87±0,88	p<0.05	p<0.05	NS
VCO <sub>2</sub> (l.min <sup>-1</sup> )	2,99±0,77	3,12±0,77	3,44±0,84	3,62±0,87	p<0.05	p<0.05	NS
Gross efficiency (%)	15.4±0.9	14.7±0.9	16.2±1.1	15.4±1.2	p<0.05	p<0.05	NS
Net efficiency (%)	17.2±1.2	16.4±1.0	17.9±1.3	16.9±1.3	p<0.05	p<0.05	NS
<i>Kinematic data</i>							
Stroke rate (min <sup>-1</sup> )	18±1	19±2	19±2	20±1	p<0.05	p<0.05	NS

Values are mean±SD. SRE and DRE: stationary and dynamic rowing ergometer; RPE: rate of perceived exertion.

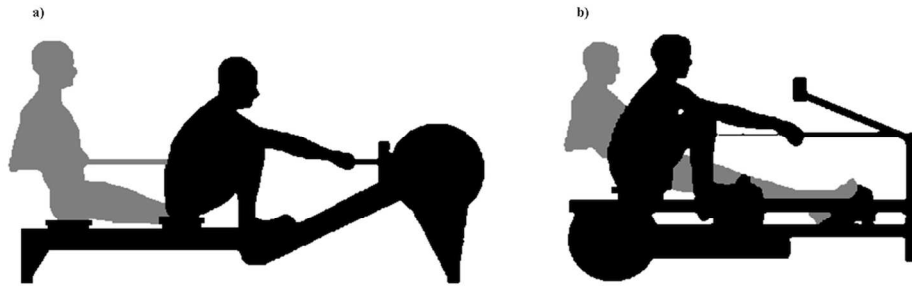


Figure 1  
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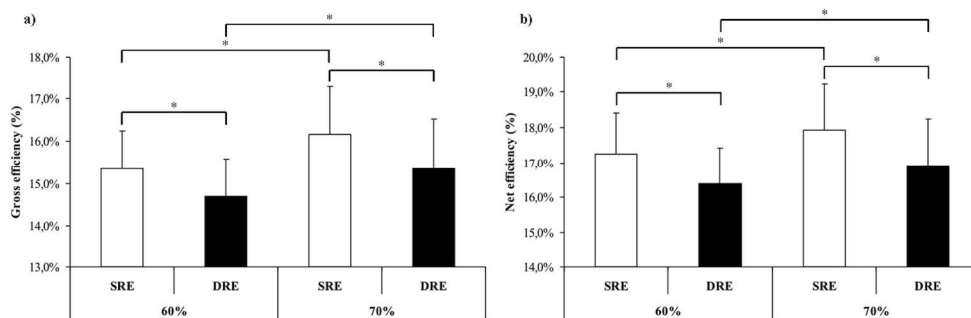


Figure 2  
244x82mm (300 x 300 DPI)

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