



# Performance and energy expenditure in cycling; effects of a specific non-circular chainring, Harmonic

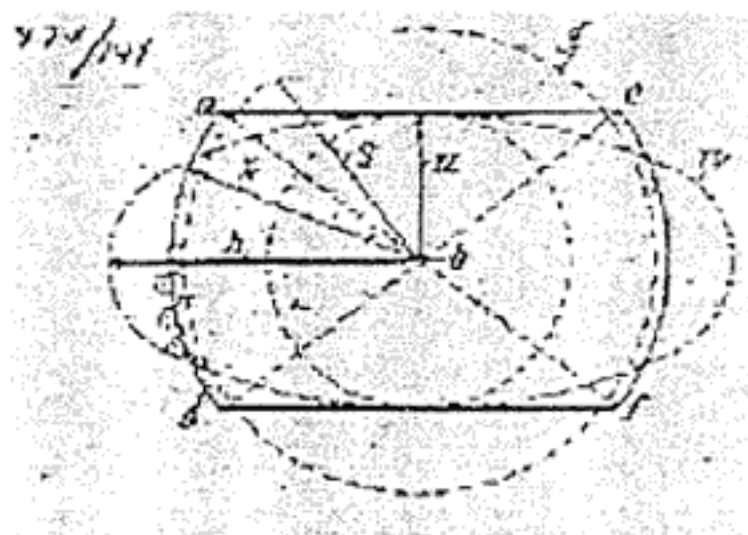
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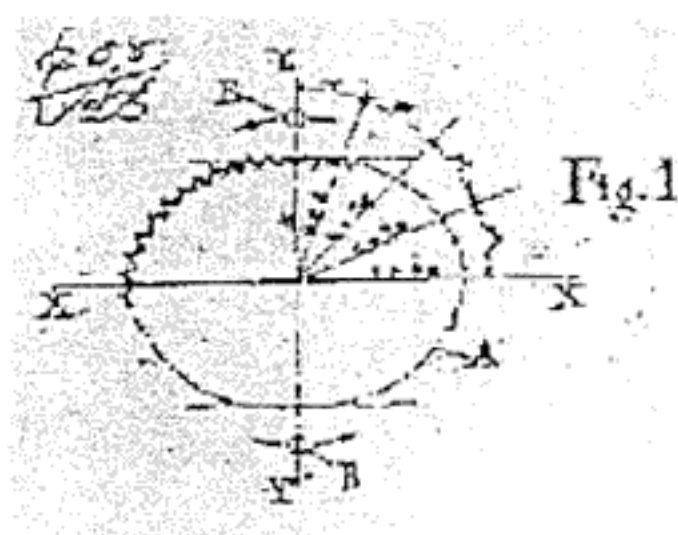
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## Introduction

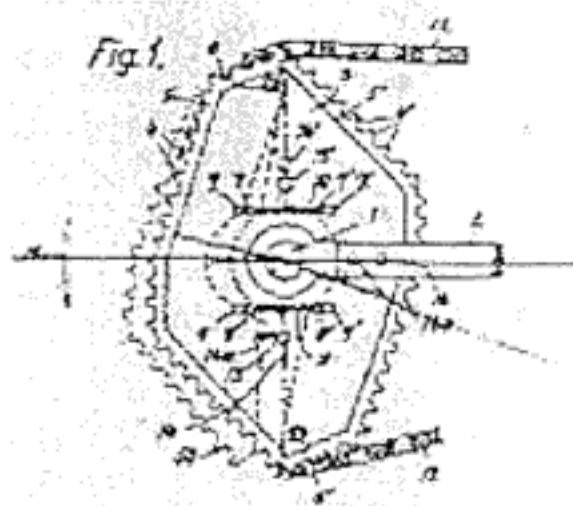
Numerous attempts of improving both the performance and the energetic expenditure of locomotion in cycling have been made by changing the force transmission system from the pedal to the rear wheel. Many of the modification are related to the use of non-circular chainrings.



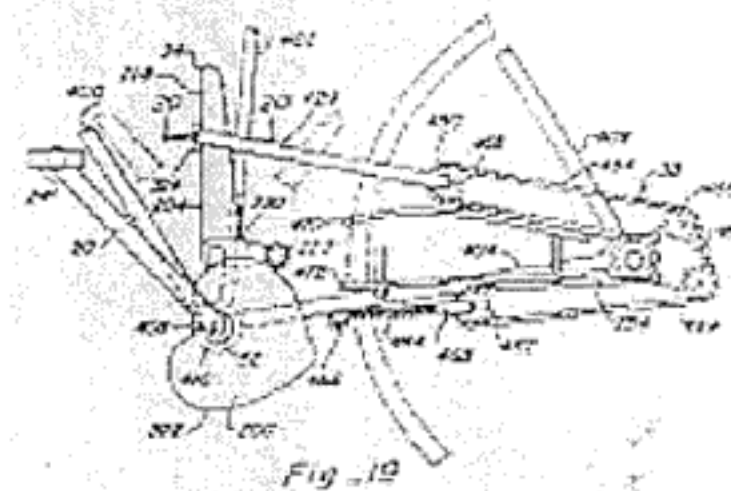
E. Rocca (1913)



E. Lantier (1928)



Carl Ejner Larsen (1946)



Brown (1979)

This choice was justified by the fact that the efficient force varies with chainring rotation (fig. 2, 3).

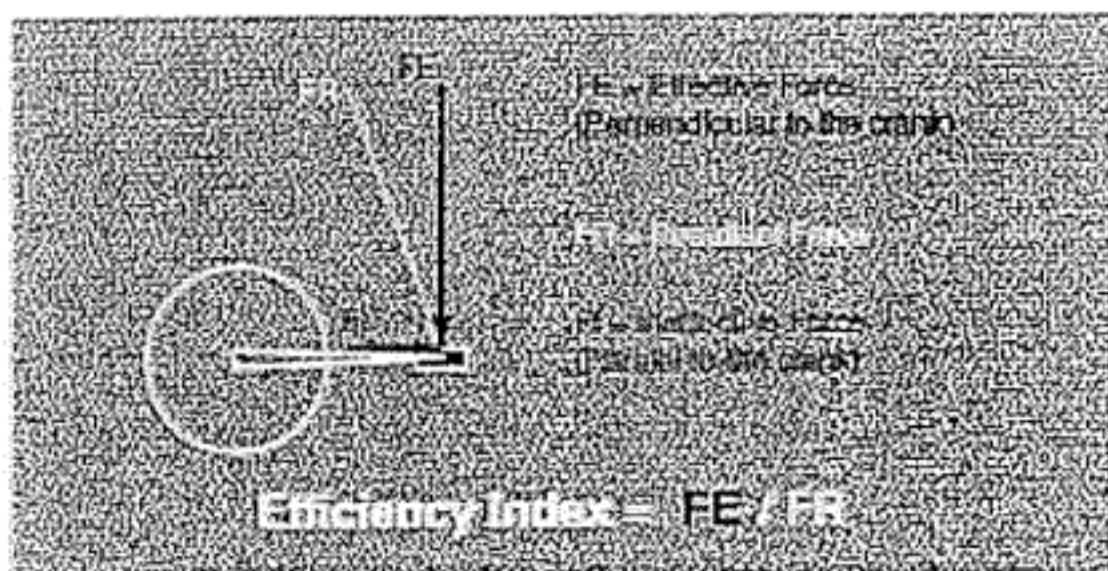


Fig. 2: The pedalling efficiency index

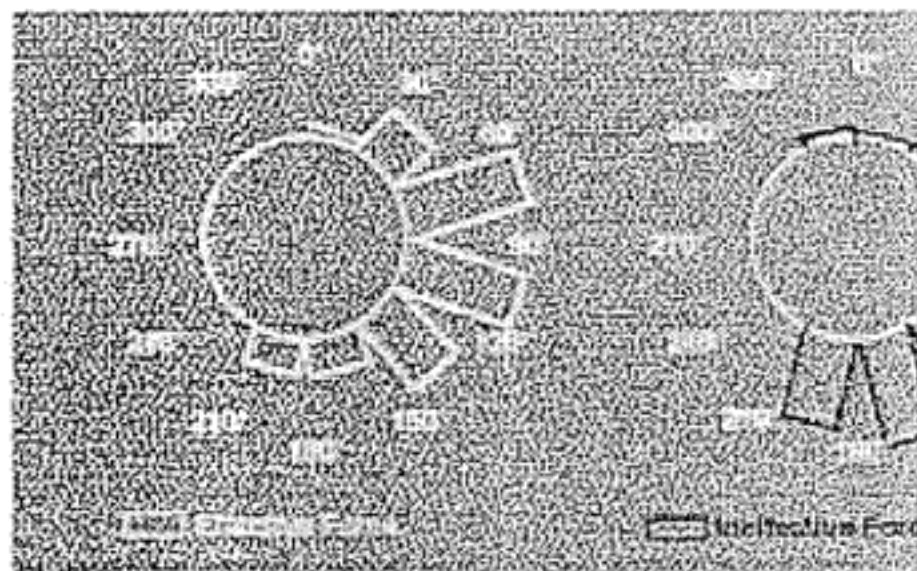


Fig. 3: Variation in effective and ineffective during a crank revolution

A brand new type of non-circular chainring "Harmonic" (Harmonic, Somovedi, Monaco), which is based on optimisation of efficient force produced during cycling has been recently introduced. The aim of our study was to test the impact of this specific chainring on the performance and the energy expenditure in cycling.

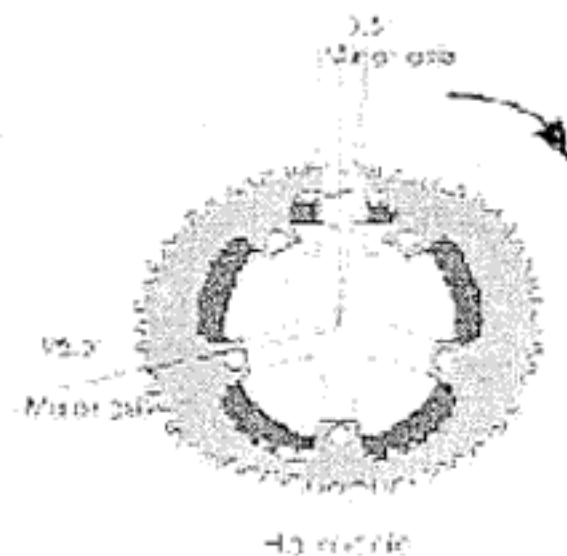


Fig. 4: The Harmonic chainring (road version)

## Methods

Twenty trained cyclists (30±8 years, 70±6 kg) took part in two progressive tests (randomized order, double blind test), led to exhaustion, with a circular chainring (CC) and with Harmonic. The cycling rate was imposed. The subjects used their own bikes, mounted on an ergometer with a torque controlled brake, and which was previously validated. Ventilation (VE), oxygen consumption (VO<sub>2</sub>) and carbon dioxide output (VCO<sub>2</sub>) were measured with an open-circuit system (EOS Sprint Jaegger). In maximal condition, the paired t-test was used. In sub-maximal condition, a two-factor variance analysis (two intra - exercise power and chainring shape - and zero inter) was made.

## Results

With Harmonic the maximum power output was significantly superior ( $316 \pm 31.70$  W vs  $301 \pm 24.62$  W,  $p < 0.001$ ) (Table 1).

Table 1 - Observed values in maximal condition (mean  $\pm$  SE).

	CC m	Harmonic m	
	<i>(T=<math>p &lt; 0.1</math>, *=<math>p &lt; 0.05</math>, ***=<math>p &lt; 0.001</math>)</i>		
Min	19.88 $\pm$ 2.16	20.65 $\pm$ 2.25	***
Watt	301 $\pm$ 24.62	316 $\pm$ 31.70	***
FC	184 $\pm$ 12.76	184 $\pm$ 13.36	
VE	127 $\pm$ 19.63	121 $\pm$ 23.72	
VO <sub>2</sub>	4.21 $\pm$ 0.60	3.91 $\pm$ 0.72	T
VCO <sub>2</sub>	4.93 $\pm$ 0.79	4.5 $\pm$ 0.88	*
QR	1.18 $\pm$ 0.12	1.15 $\pm$ 0.07	*

### In sub-maximal condition

The difference of VO<sub>2</sub> was of 3.5% but not significant ( $p = 0.078$ ). Yet the interaction effect (power \* chaining type) was significant ( $p > 0.001$ ) for VO<sub>2</sub>, VE and VCO<sub>2</sub>, showing that the difference was increasing with the exercise intensity (fig. 5).

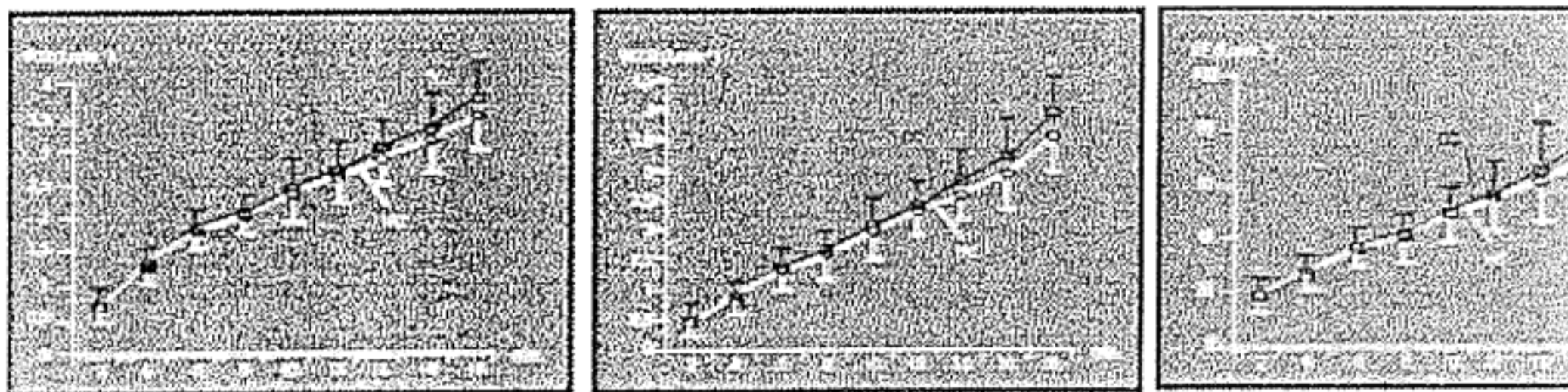


Fig. 5: Summary of main results in sub-maximal condition for VO<sub>2</sub>, VCO<sub>2</sub>, VE for each sub-maximal load (\*=significant difference)

### Discussion

The present results are different from those obtained by Hull (1992) during sub-maximal exercises, and using non circular chainrings with different shapes compared to Harmonic (Biopace Shimano, Eng 10, Eng 90).

The greater power output observed in maximal condition, and the lower energy cost observed when power is between 70 and 100% of maximal power output can be explained by an increase in pedalling efficiency index (fig. 2) with Harmonic. The greater effective gearing when the crank is near the horizontal position determines an increase in external mechanical work when the pedalling efficiency index is optimal. On the other hand, mechanical work when pedalling efficiency index is minimal is reduced (fig. 3).

### Conclusion

The improvement in performance and the reduced energy cost measured with Harmonic compared to CC clearly indicates a better efficiency of Harmonic (i.e. a greater ratio FE/FR). Therefore, force transmission from the pedal to the rear wheel is optimized by taking into account the variations of the efficient force (FE) during cycling.

### Readings

- Hull, M. L., Williams, M., Williams, Kautz, S., "Physiological response to cycling with both circular and non-circular chainrings ", *Medecine and Science in Sports and Exercice* , 24:10, pp. 1114-1122, 1992.
- Patterson R. and M. Moreno. "Bicycle pedalling forces as a function of pedalling rate and power output ", *Medecine and Science in Sports and Exercice* , 22:4, pp. 512-516, 1990.
- Sanderson D.J., "The influence of cadence and power output on the biomechanics of force application during steady-state cycling in competitive and recreational cyclists ", *Journal of Sciences of Sports*. 9, pp. 191-203, 1991.
- Saden, P.D. and B.A. Adeyeta. "Forces applied to a bicycle during normal cycling ". *J. Biomech.* 12, pp. 527-541, 1979.

Fig. 12 - Comparison of the  $V_{O_2}$  (average and type difference) for each stage in sub : maximal condition (\* : significant difference).

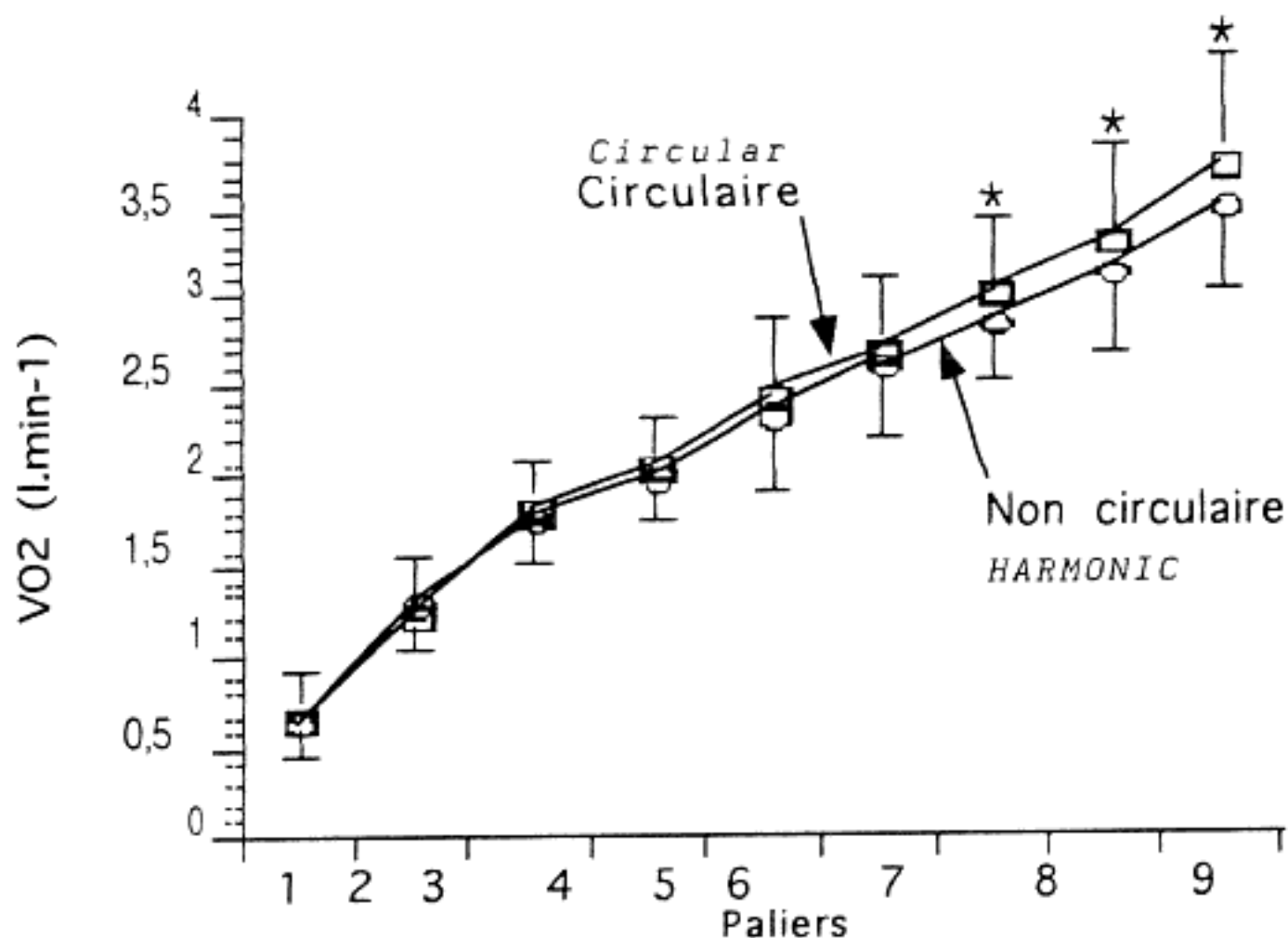


Figure 12 : Comparaison des  $V_{O_2}$  (moyenne et écart type) pour chaque palier sous maximal. (\* = différence significative)

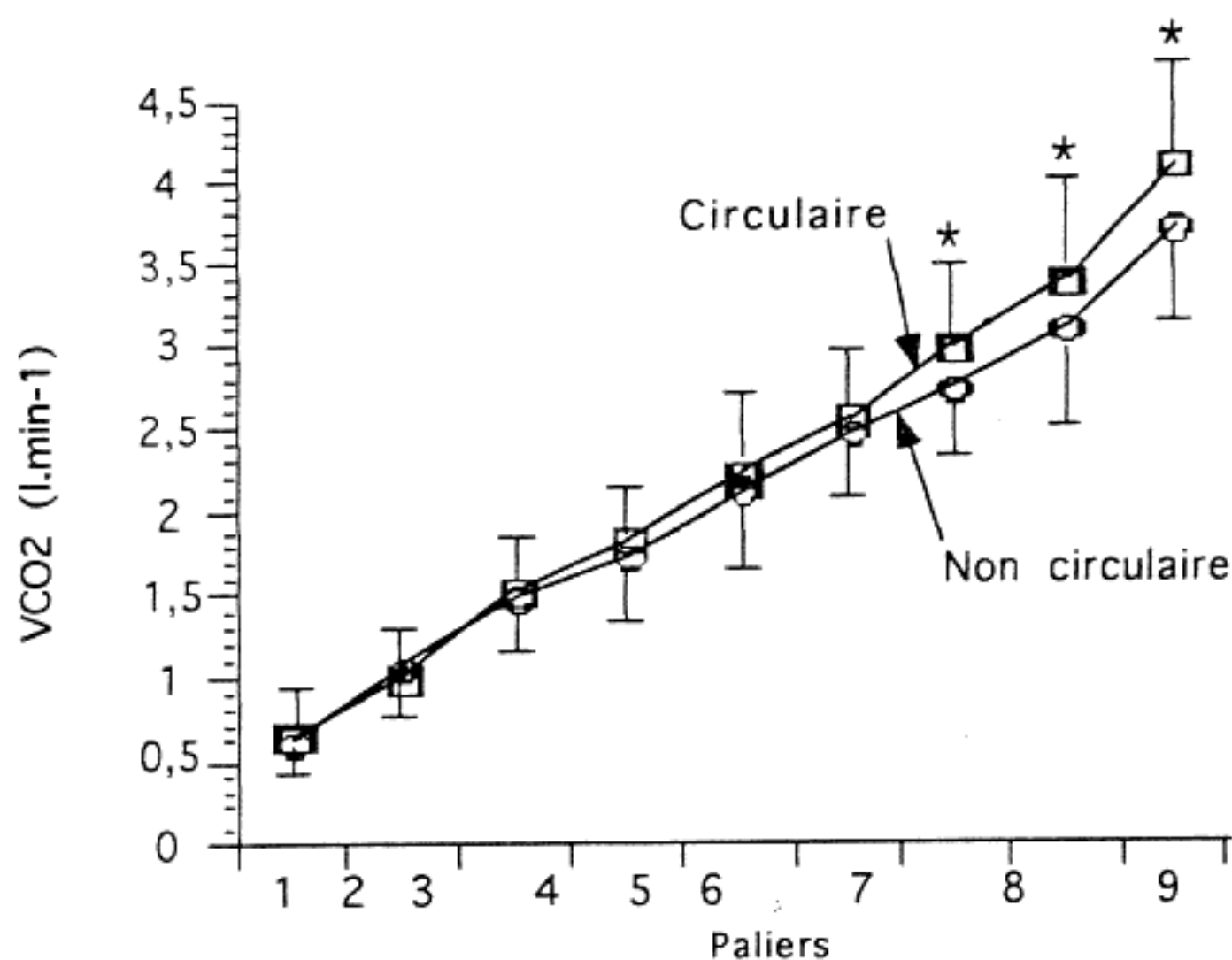
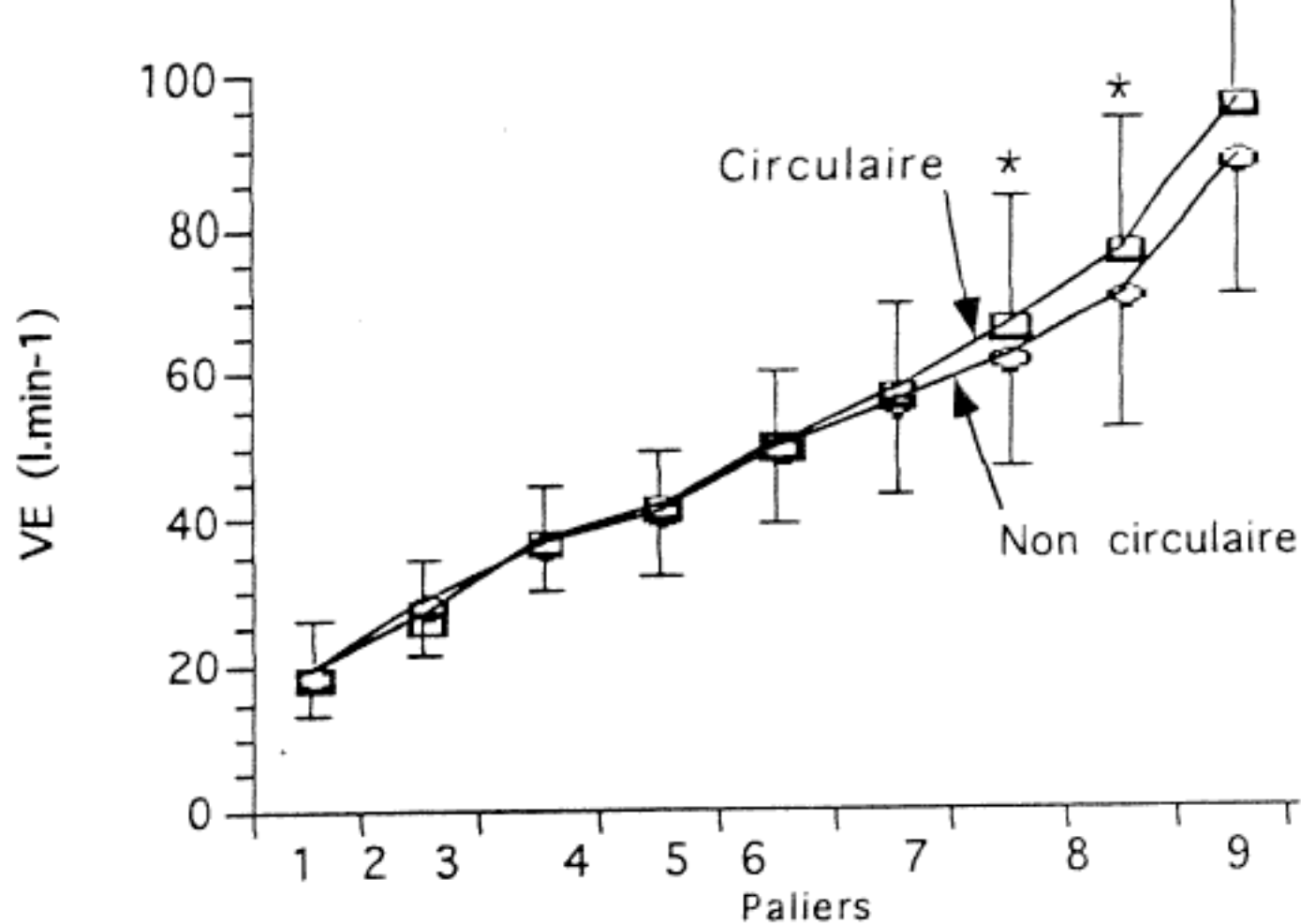


Figure 13 : Comparaison des  $V_{CO_2}$  (moyenne et écart type) pour chaque palier sous maximal. (\* = différence significative)

Figure 13 : Comparison of the  $V_{CO_2}$  (average and type difference), for each stage in sub. : maximal condition (\* : significant difference)



**Figure 14** : Comparaison des VE (moyenne et écart type) pour chaque palier sous maximal.  
 (\* = différence significative)

Figure 14 : Comparison of the VE (average and type difference), for each stage in sub. maximal condition (\* : significant difference).