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

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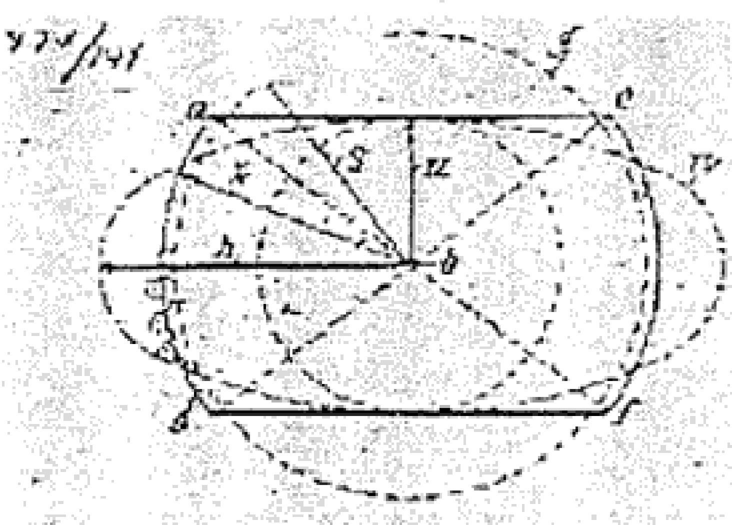
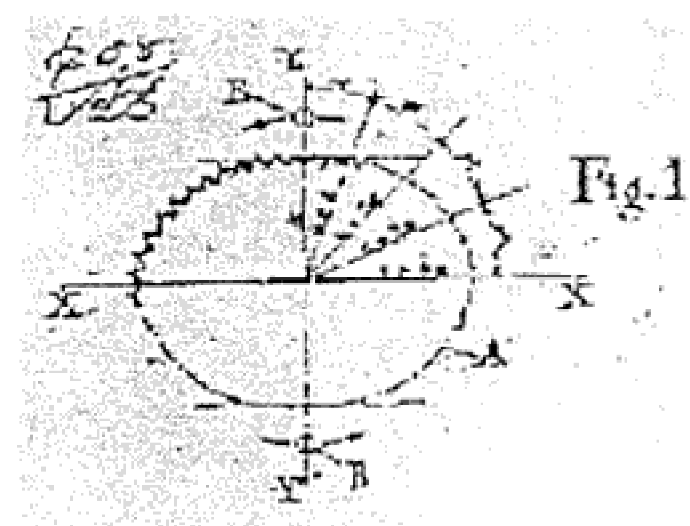
Introduction

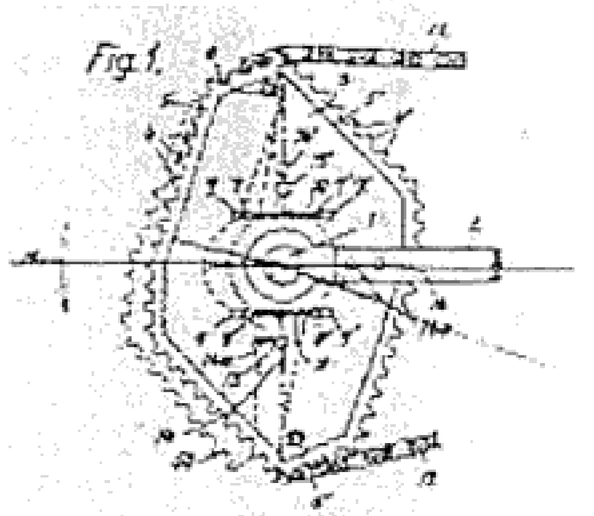
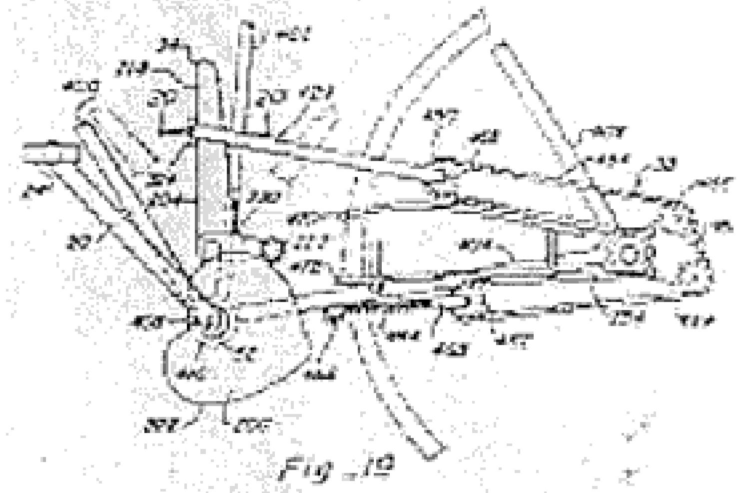
Numerous attempts of improving both the performance and the energetic expenditure of locomotion in cycling have been made by changing the force transmission system form the pedal to the rear wheel. Many of the modification are related to the use of non-circular chainrings.



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).

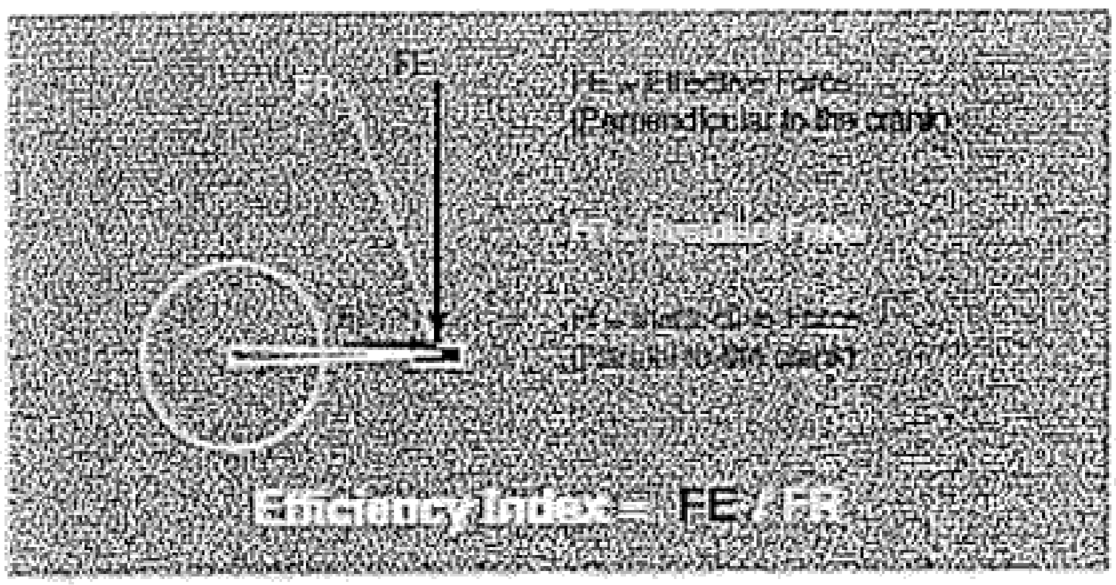


Fig. 2: The pedalling efficiency index

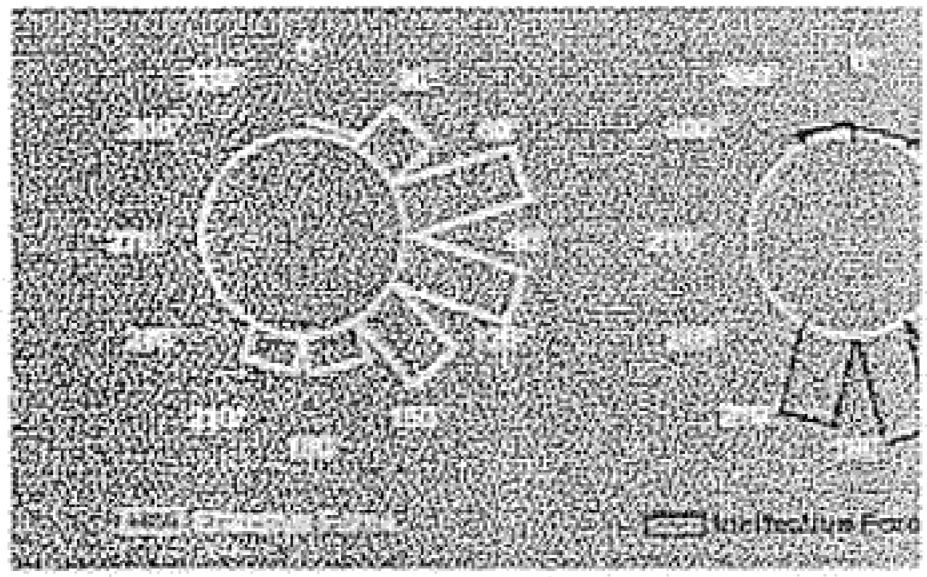


Fig. 3: Variation in effective and ineffectiv during a crank revolution

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.

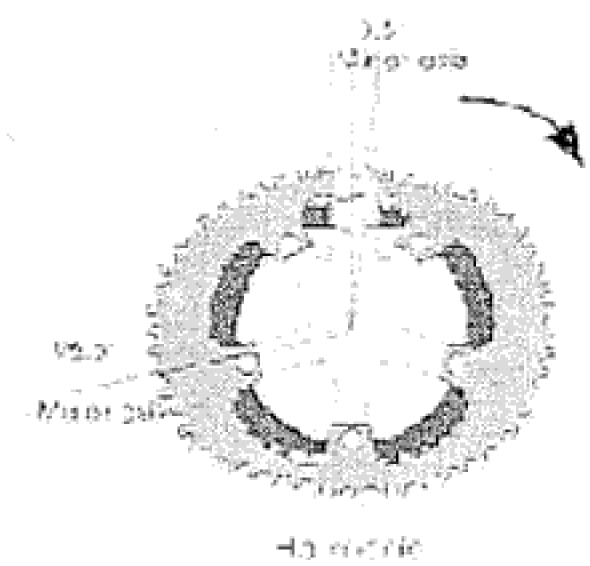


Fig. 4: The Harmonic chainring (road ver:

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 torke controled brake, and which was previously validated. Ventilation (VE), oxygen consumption (VO and carbon dioxyde output (VCO2) were measured with an open-circuit system (EOS Sprint Jaegger). In maximal condition, the pared t-test was used. In sub-maximal condition, a two-factor variance analysis (two intra - exercice power and chainring shape - and zero inter) was made.

Results

With Harmonic the maximum power ouput was signicantly superior (316+/-31.70 W vs 301+/-24.62 W, p<0.001) (Table 1).

Table 1 - Observed values in maximal condition (mean +/- SE).

	CC m	Harmonic m	
	(T=p<0.1, *=p<0.05, ***=p<0.001)		
Min	19.88 +/-2.16	20.65 +/-2.25	***
Watt	301 +/-24.62	316 +/-31.70	***
FC	184 +/-12.76	184 +/-13.36	
VE	127 +/-19.63	121 +/-23.72	
VO2	4.21 +/-0.60	3.91 +/-0.72	T
VCO2	4.93 +/-0.79	4.5 +/-0.88	*
QR	1.18 +/-0.12	1.15 +/-0.07	*

In sub-maximal condition

The difference of VO2 was of 3.5% but not significant (p=0.078). Yet the interaction effect (power * chainring type) was significant (p>0.001) for VO2, VE and VCO2, showing that the difference was increasing with the exercise intensity (fig. 5).

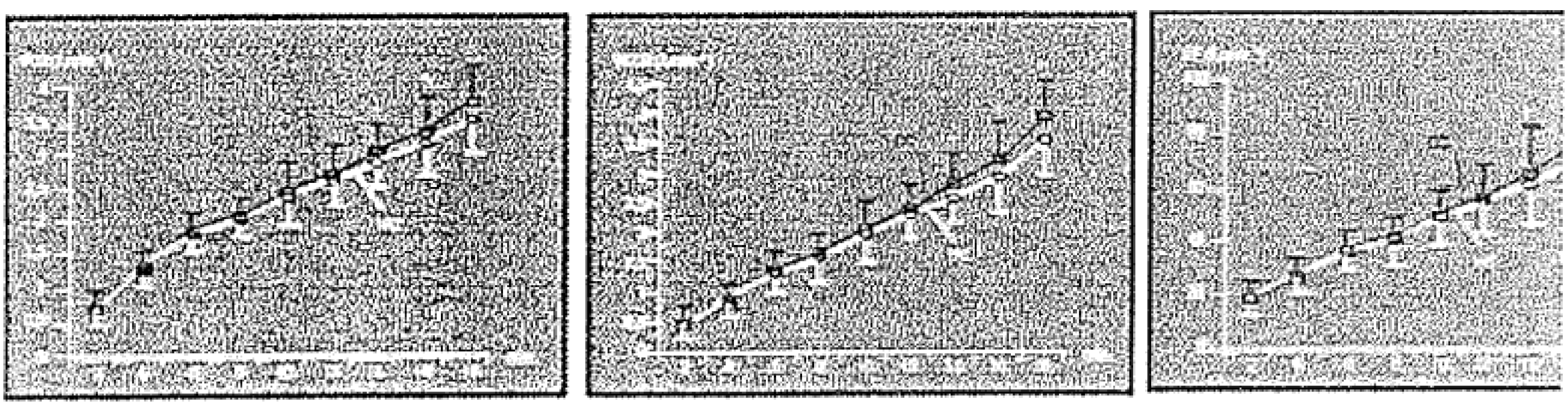


Fig. 5: Summary of main results in sub-maximal condition for VO2, VCO2, VE for each sub-maximal l. (=significant difference)*

Discussion

The present results are different from those obtained by Hull (1992) during sub-maximal exercices, 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 mechanic work when the pedalling efficency index is optimal. On the other hand, mechanical work when pedalling efficency 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 form 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 th ebiomechanics of force application during steady-state cycling in competive 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 VO2 (average and type différence) for each stage in sub : maximal condition (* : significant différence).

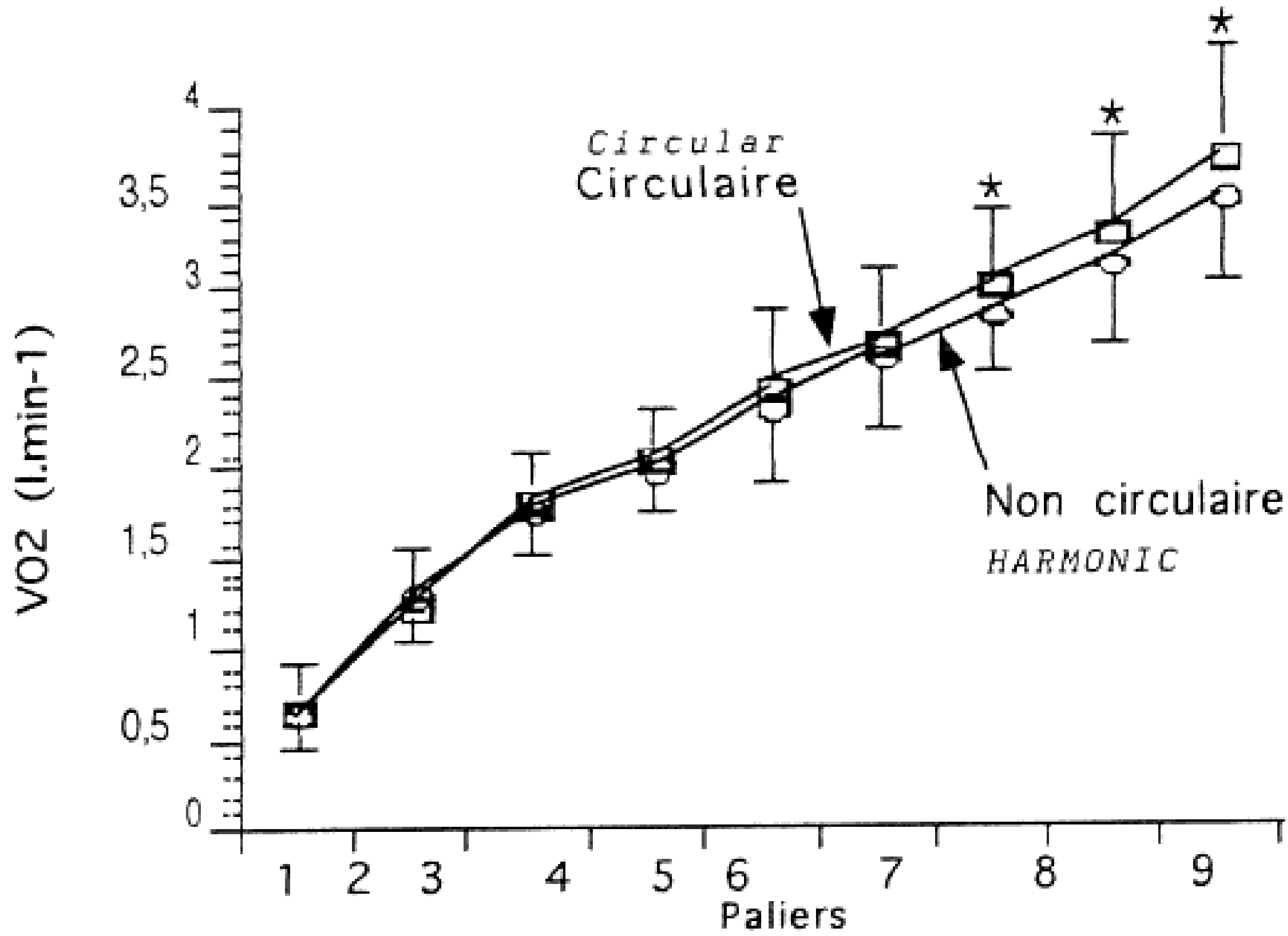


Figure 12 : Comparaison des VO2 (moyenne et écart type) pour chaque palier sous maximal. (* = différence significative)

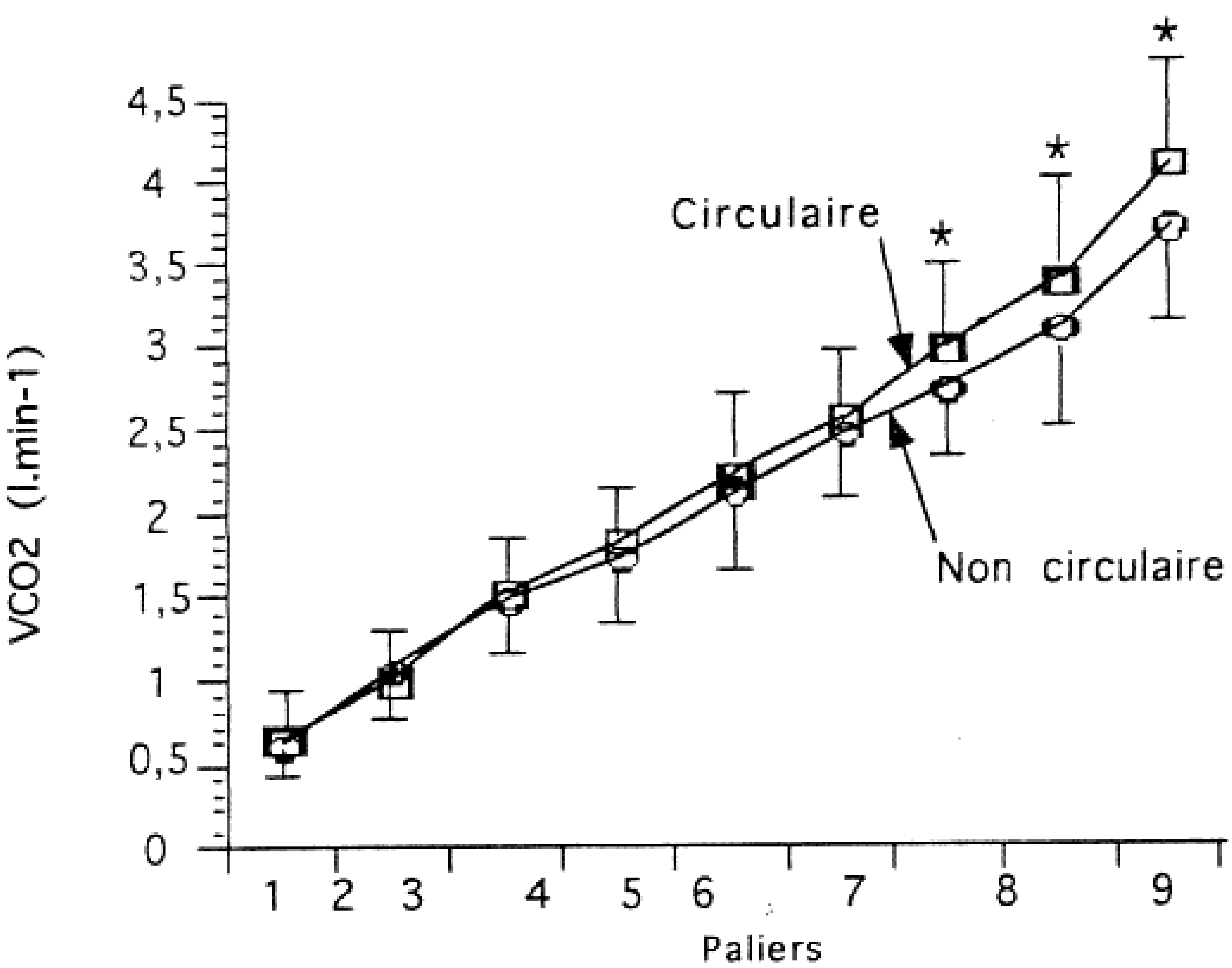


Figure 13 : Comparaison des VCO2 (moyenne et écart type) pour chaque palier sous maximal. (* = différence significative)

Figure 13 : Comparison of the VCO2 (average and type différence), for each stage in sub. : maximal condition (* : significant différence)

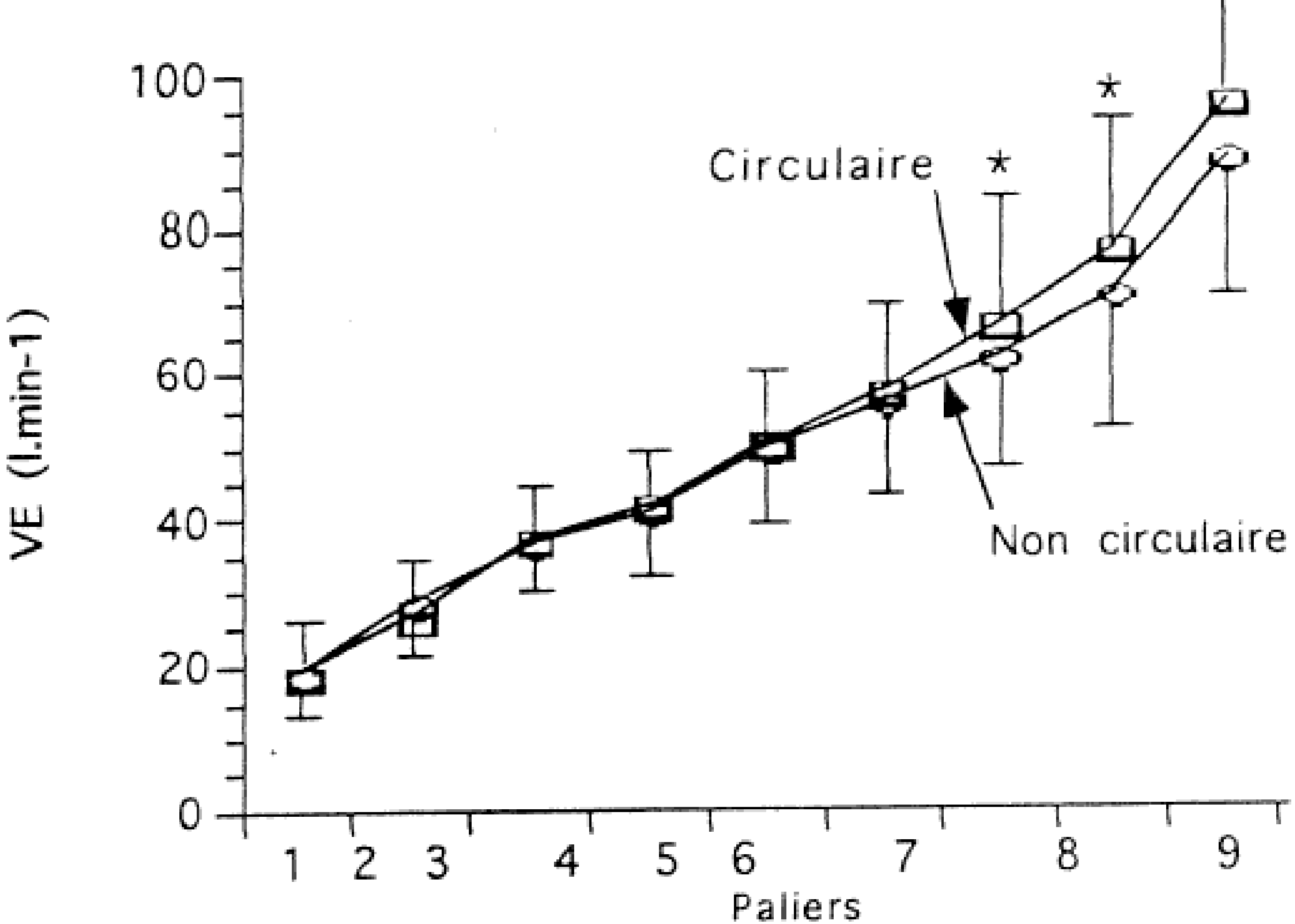


Figure 14 : Comparaison des VE (moyenne et écart type) pour chaque palier sous maximal.
(* = différence significative)

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