

# Endurance training minimizing carbohydrate oxidation by targeting the optimal level of fat/carbohydrate oxidation ratio (OLORFOX)?

*Entraînement en endurance minimisant l'oxydation des glucides grâce au ciblage au niveau optimal de rapport d'oxydations lipides/glucides (NOROLG) ?*

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## KEYWORDS

Obesity;  
Exercise;  
Training;  
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Weight loss

## Summary

*Introduction and purpose.* – The effectiveness of endurance training at low to moderate intensities targeted at the level of maximal lipid oxidation (LIPOXmax) is confirmed by recent international work. It may seem paradoxical, given the low level of caloric expenditure involved. One of the explanations for this paradox is that LIPOXmax training has epigenetic effects and regulatory effects on eating behavior. Indeed, exercise at this level favors satiety and reduces the urge to snack, whereas at higher intensity, in the lipid oxidation zone, 30 to 60 minutes of endurance exercise favors food intake and may determine a paradoxical weight gain.

*Methods and results.* – In our previously published database of 3739 calorimetries we have recalculated the kinetics of the lipid/carbohydrate oxidation ratio and we observe that it peaks

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## MOTS CLÉS

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on average 12% below LIPOXmax ( $39.45\% \pm 0.20\%$  vs.  $44.87\% \pm 0.23\%$  VO<sub>2</sub>max;  $P < 0.0001$ ) at a level we propose to call "optimal level of fat/carbohydrate oxidation ratio" (OLORFOX) and that this level may present in many cases wide inter-individual variations, so that there are profiles of subjects in whom it is frankly disjointed from that of LIPOXmax. A preliminary series of 11 patients with this profile who were trained at OLORFOX confirms that this approach over 3 years is effective for weight loss ( $-11.5 \pm 1.5\%$  of initial weight  $P < 0.001$ ), even though this level is set below the LIPOXmax which is itself located at a low to moderate intensity.

*Conclusion.* – These preliminary data lead us to study more widely this type of targeting of training in overweight individuals.

## Résumé

*Introduction et objectif.* – L'efficacité de l'entraînement en endurance à des intensités faibles à modérées ciblée sur le niveau d'oxydation lipidique maximale (LIPOXmax) est confirmée par de récents travaux internationaux. Elle peut sembler paradoxale compte tenu du faible niveau de dépense calorique mis en jeu. Une des explications de ce paradoxe tient à des effets épigénétiques et à des effets régulateurs sur le comportement alimentaire. En effet l'exercice à ce niveau favorise la satiété et diminue les pulsions de grignotage tandis qu'à plus haute intensité, dans la zone d'oxydation lipidique, des exercices de 30 à 60 minutes en endurance favorisent la prise alimentaire et peuvent déterminer une prise de poids paradoxale.

*Méthodologie et résultats.* – Dans notre base de données 3739 calorimétries (2490 femmes et 1249 hommes) nous avons recalculé la cinétique du rapport d'oxydations lipides/glucides et nous observons qu'il culmine en moyenne 12 % au-dessous du LIPOXmax ( $39,45\% \pm 0,20\%$  vs  $44,87\% \pm 0,23\%$  de VO<sub>2</sub>max ;  $p < 0,0001$ ) mais avec beaucoup de variations interindividuelles et qu'il y a des profils de sujets chez qui ce niveau est franchement disjoint de celui du LIPOXmax. Une série préliminaire de 11 patients présentant ce profil « biphasique » et entraînés au NOROLG confirme que cette démarche sur 3 ans est efficace pour perdre du poids ( $-11,5 \pm 1,15\text{ kg}$   $p < 0,0001$ ) alors même que ce niveau est situé au-dessous du LIPOXmax qui est lui-même situé à une intensité faible à modérée.

*Conclusion.* – Ces premières données poussent à étudier plus largement ce type de ciblage du réentraînement dans les surcharges pondérales.

## 1. Introduction

The effectiveness of endurance training at low to moderate intensities targeting the level of maximum lipid oxidation (LIPOX max) is confirmed by recent international work [1]. It may seem paradoxical, given the low level of caloric expenditure involved. Among the explanations for this paradox, we can mention epigenetic effects [2] and regulatory effects on eating behavior [3]. Indeed, exercise at this level promotes satiety and reduces the urge to snack while at higher intensity, in the CHO oxidation zone, 30 to 60 minute endurance exercises promote food intake [4] so that exercise targeted at a higher level may often induce a paradoxical weight gain [5].

All this leads to think that exercising in the lipid oxidation zone vs. the CHO oxidation zone has markedly different physiological effects. In some cases, exercise calorimetry evidences a very biphasic exercise calorimetry profile, with a fair ability to oxidize fat narrowly localized at a low intensity, and above this level a massive utilization of carbohydrates. Such a profile has been evidenced in hypothyroid patients treated with levothyroxine [6]. It is well known [7,8] that hypothyroid patients are prone to weight gain and that it is not easy to help them to lose weight. On the

basis of this finding, we hypothesized that targeting exercise sessions more closely at these low intensity levels would even better spare oxidation of carbohydrates. We therefore aimed at evaluating this new concept of metabolic targeting level of endurance training for weight reduction.

## 2. Materials and methods

### 2.1. Subjects

In our previously presented database of 3739 calorimetry (2490 women and 1249 men, 15 to 85 years old, 65.4% of them being obese), with an average body mass index (BMI) of  $32.87\text{ kg/m}^2$  [9] we have calculated the kinetics of the lipid/carbohydrate oxidation ratio in order to determine at which intensity level OLORFOX is found in comparison with the LIPOXmax, and if these two levels are correlated or dissociated. Characteristics of this sample are shown on Table 1.

### 2.2. Adapted physical activity

Extended follow-up results are available over 57 months for 11 subjects (10 females/1 male), weight 58.3–116 kg,

**Table 1** Characteristics of the 3739 patients of the database used for defining reference ranges for OLORFOX. Subjects are 15 to 85 years old, with an average body mass index (BMI) of 32.87 kg/m<sup>2</sup>. Their average LIPOXmax is 42.8 watt (2nd and 3rd quartile ranging between 29.6 and 56.0 watt), which corresponds to 44.87%±0.23% of maximal aerobic capacity (VO<sub>2</sub> max), calculated according to the American College of Sports Medicine (ACSM). OLORFOX is on the average 5.4% of VO<sub>2</sub>max lower than LIPOXmax (*P* < 0.0001), which means that it is 12% lower than LIPOXmax.

Gender (F/M)	2490/1249
Age	15 to 85 years
Weight (kg)	90.9 ± 0.35
Fat free mass	54.7 ± 0.21
Fat mass (%)	39.8 ± 0.18
Muscle mass (kg)	19.1 ± 0.21
Waist circumference	102.8 ± 0.33
Hip circumference	113.5 ± 0.55
VO <sub>2</sub> max ACSM	25.8 ± 0.28
OLORFOX %VO <sub>2</sub> max	39.45% ± 0.20%
LIPOXmax % VO <sub>2</sub> max	44.87% ± 0.23%
Difference level between OLORFOX and LIPOXmax	5.42% ± 0.19%

OLORFOX: optimal level of fat/carbohydrate oxidation ratio; LIPOXmax: maximal lipid oxidation; F: female; M: male.

age 37–68 years, BMI 22.8–48.7 kg/m<sup>2</sup>. Characteristics of patients are shown on [Table 2](#).

Low intensity endurance physical activity (3 × 45 min/week) was targeted at the OLORFOX following an exercise calorimetry based on 6-minute steps performed at steady state as previously published [10]. Calorimetric calculation is performed on the averaged values of the last two minutes of each stage [11]. Eight training-induction sessions were carried out in hospital on a cycloergometer, with patients being encouraged to perform a similar level of activity of equal or greater volume, as

**Table 2** Characteristics of the 11 patients who underwent a 3-year training targeted at the OLORFOX.

Gender (M/F)	1 M/11 F
Weight (kg)	85.5 ± 4.8 (58.3 to 116)
Age (years)	56.2 ± 3.5 (37 to 68)
Height (cm)	159.9 ± 2.1 (151 to 172)
Excess weight (kg)	19.6 ± 2.7 (12.8 to 32.1)
BMI (kg/m <sup>2</sup> )	34.4 ± 2.3 (22.8 to 48.7)
Waist circumference (cm)	105 ± 3 (93 to 120)
Hip circumference (cm)	117.3 ± 4.0 (104 to 137)
Fat free mass (kg)	49.0 ± 2.5 (40.3 to 66.6)
Fat mass (kg)	39.5 ± 4.2 (25.2 to 60.8)
BP max	136.67 ± 3.29 (130 to 152)
BP min	74.5 ± 3.36 (66 to 86)
Energy intake (kcal/day)	1604.3 ± 247.5 (1183 to 2040)
Protein intake g.kg <sup>-1</sup> d <sup>-1</sup>	0.7 ± 0.2 (0.5 to 1)
% Protein	13.5 ± 2.5
% CHO	64.5 ± 4.5
% Lipids	22.0 ± 2.0

OLORFOX: optimal level of fat/carbohydrate oxidation ratio; F: female; M: male; CHO: carbohydrate oxidation rate.

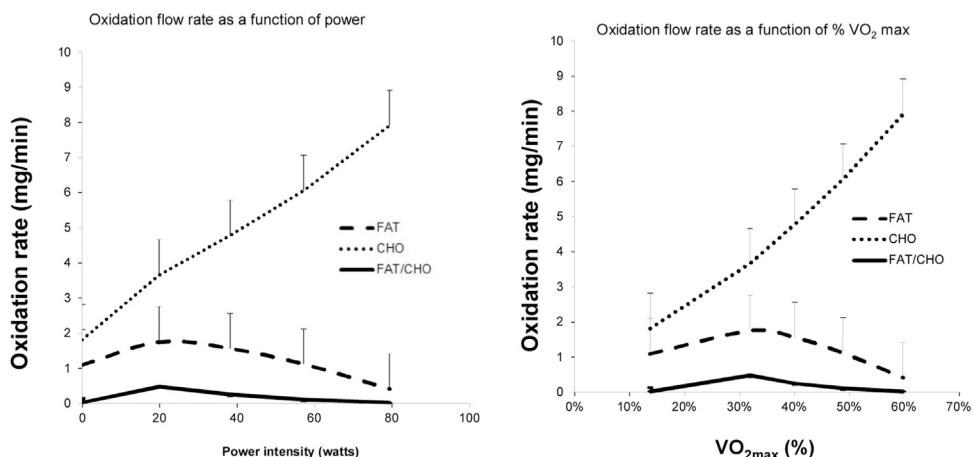
part of their daily lives, and being followed up regularly in an outpatient clinic to ensure long-term compliance and to check the effectiveness and correct implementation of training.

### 2.3. Statistics

Comparisons were made using Student's *t*-test, Chi<sup>2</sup> test, and ANOVA as appropriate. A value of *P* < 0.05 is considered significant.

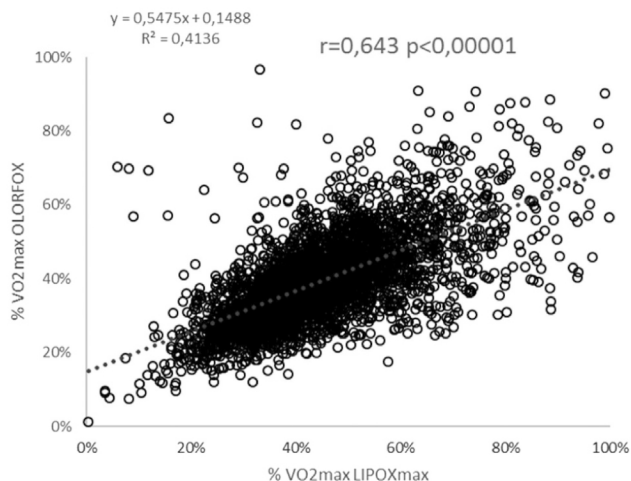
## 3. Results

On the previously published database of 3739 patients [9] the average LIPOXmax is found at 42.83 watt (2nd and



**Figure 1** Average kinetics of the optimal level of fat/carbohydrate oxidation ratio (OLORFOX) compared to that of CHO and lipid oxidation, showing that it peaks 12% lower than the maximal lipid oxidation (LIPOXmax) (39.45% ± 0.20% vs. 44.87% ± 0.23% VO<sub>2</sub>max; *P* < 0.0001). FAT: lipid oxidation rate; CHO: carbohydrate oxidation rate; FAT/CHO: ratio of oxidation of fat on oxidation of carbohydrates (= OLORFOX).

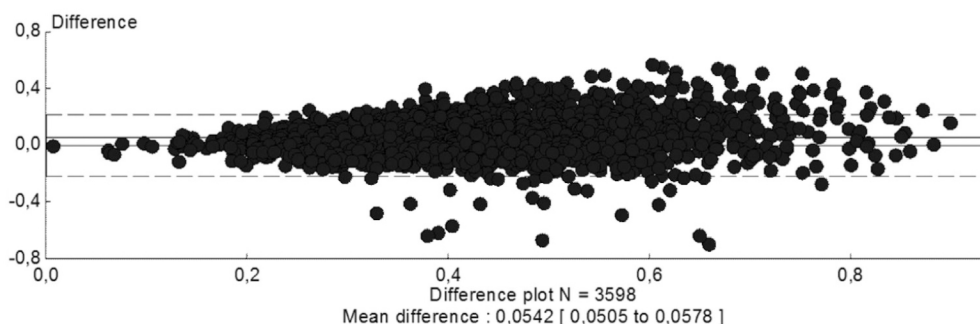




**Figure 2** Correlation between the %VO<sub>2</sub>max where there is a peak of optimal level of fat/carbohydrate oxidation ratio (OLORFOX) vs. a peak of maximal lipid oxidation (LIPOXmax).

3rd quartile ranging between 29.58 and 56.0 watt), which corresponds to  $44.87\% \pm 0.23\%$  of maximal aerobic capacity (VO<sub>2</sub> max), calculated according to American College of Sports Medicine (ACSM). Maximal lipid oxidation rate was  $203.44 \pm 95$  mg/min (mean  $\pm$  SD). There was no longer lipid oxidation above 84.81 watt (upper limit of the lower quartile: 60.39 watts and lower limit of the upper quartile: 109.23 watts), corresponding to 69% of VO<sub>2</sub> max ACSM. The average slope of the linear relationship between CHO oxidation and power (carbohydrate cost of the watt) is  $0.25 \pm 0.09$  mg min<sup>-1</sup> kg<sup>-1</sup> W<sup>-1</sup>. As shown in Table 1, the calculations of the kinetics of the lipid/carbohydrate oxidation ratio shows that it is found at an average percentage of VO<sub>2</sub>max ACSM of  $39.45\% \pm 0.20\%$ , i.e.  $5.42\% \pm 0.19\%$  lower (in % of VO<sub>2</sub>max) which means that it is proportionally 12% lower ( $P < 0.0001$ ) than LIPOXmax. This discrepancy can be seen on Figs. 1–3.

We have recalculated the kinetics of the lipid/carbohydrate oxidation ratio and we observe that it peaks on average 8% below LIPOXmax but with a lot of inter-individual variations and that there are profiles of subjects in whom this level is frankly disjointed from that of LIPOXmax.



**Figure 3** Bland–Altman plot showing the agreement between optimal level of fat/carbohydrate oxidation ratio (OLORFOX) and maximal lipid oxidation (LIPOXmax) both expressed as a fraction of VO<sub>2</sub>max. This graph shows that OLORFOX is found 5.42% VO<sub>2</sub>max below LIPOXmax, i.e., is 12% below it.

As shown on Fig. 4, a preliminary series of patients with this profile and re-trained at OLORFOX confirms that this approach over 3 years is effective for weight loss even though this level is below the LIPOXmax itself located at a low to moderate intensity. On the average patients have lost  $9.7 \pm 1.3$  kg i.e.  $-11.5 \pm 1.5\%$  of initial weight  $P < 0.001$ , thus representing  $51.09 \pm 6.85\%$  of the initial excess weight.

#### 4. Discussion

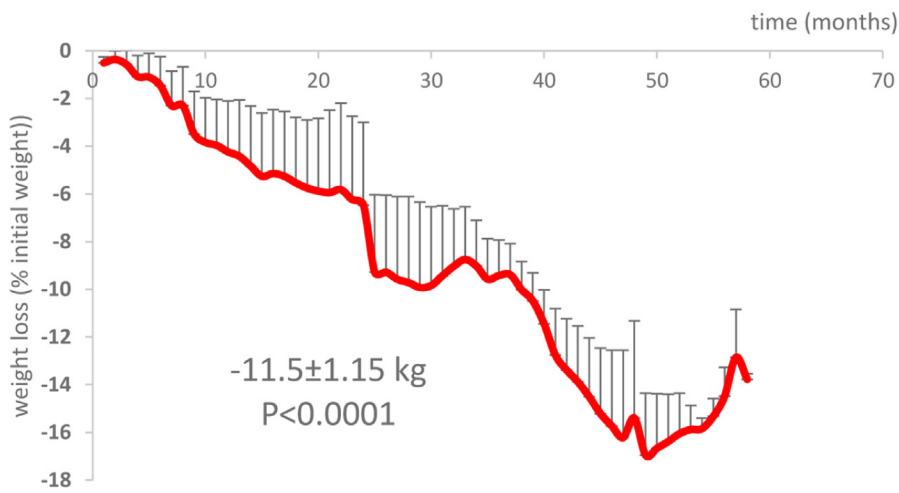
Therefore we find that (a) OLORFOX is most of the time found below LIPOXmax but with a wide variability; (b) selecting this level in individuals who exhibit a marked biphasic pattern of substrates oxidation at exercise (in this case L-thyroxin treated hypothyroid subjects) makes low intensity low volume exercise training efficient for losing weight over 60 months.

More studies are needed but this pilot study is a ‘‘proof of concept’’ indicating that OLORFOX, despite its very low intensity, is a target for exercise training that may be interesting for improving body composition in some patients.

Whether low intensity low volume exercise training has some biological efficacy appeared almost doubtful to most specialists 20 years ago, but the series of studies (‘‘STRIDE’’, i.e., ‘‘Studies of a Targeted Risk Reduction Intervention through Defined Exercise’’) have provided a serious basis for this concept. These randomized controlled studies have demonstrated that a low volume of exercise training targeted at low intensity has even stronger effects on fat deposits and insulin sensitivity than exercise targeted at higher intensity levels [12,13]. Even more, it was shown that even a modest amount of this kind of exercise is able to counteract obesity evolution and its deleterious metabolic effects [14]. Obviously, calorie deficit, which is most often considered as the explanation of exercise effects on weight and metabolism cannot explain such an effect. It was shown that even with a low-calorie deficit, there was a release of skeletal muscle metabolites, such as succinate, which with improved several disturbances, including the obesity-related defect in insulin sensitivity [15].

Although this study is still preliminary, it seems reasonable to conclude that an approach as ‘soft’ as training targeted at the intensity level of OLORFOX, which is rather easy to implement on the long-term and very well tolerated, has an effect on weight loss and allows it to last longer.





**Figure 4** Effects of training at optimal level of fat/carbohydrate oxidation ratio (OLORFOX) in 11 L-thyroxin treated hypothyroid subjects.

## Disclosure of interest

The authors declare that they have no competing interest.

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