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Short report

Effects of adipose tissue distribution on maximum lipid oxidation rate during exercise in normal-weight women

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Abstract

Aim. – Fat mass localization affects lipid metabolism differently at rest and during exercise in overweight and normal-weight subjects. The aim of this study was to investigate the impact of a low *vs* high ratio of abdominal to lower-body fat mass (index of adipose tissue distribution) on the exercise intensity ($\text{Lipox}_{\text{max}}$) that elicits the maximum lipid oxidation rate in normal-weight women.

Methods. – Twenty-one normal-weight women (22.0 ± 0.6 years, 22.3 ± 0.1 kg.m^{-2}) were separated into two groups of either a low or high abdominal to lower-body fat mass ratio [L-A/LB ($n = 11$) or H-A/LB ($n = 10$), respectively]. $\text{Lipox}_{\text{max}}$ and maximum lipid oxidation rate (MLOR) were determined during a submaximum incremental exercise test. Abdominal and lower-body fat mass were determined from DXA scans.

Results. – The two groups did not differ in aerobic fitness, total fat mass, or total and localized fat-free mass. $\text{Lipox}_{\text{max}}$ and MLOR were significantly lower in H-A/LB *vs* L-A/LB women (43 ± 3% $\text{VO}_{2\text{max}}$ *vs* 54 ± 4% $\text{VO}_{2\text{max}}$, and 4.8 ± 0.6 mg min^{-1} kg FFM^{-1} *vs* 8.4 ± 0.9 mg min^{-1} kg FFM^{-1}, respectively; $P < 0.001$). Total and abdominal fat mass measurements were negatively associated with $\text{Lipox}_{\text{max}}$ ($r = –0.57$ and $r = –0.64$, respectively; $P < 0.01$) and MLOR [$r = –0.63$ ($P < 0.01$) and $r = –0.76$ ($P < 0.001$), respectively].

Conclusion. – These findings indicate that, in normal-weight women, a predominantly abdominal fat mass distribution compared with a predominantly peripheral fat mass distribution is associated with a lower capacity to maximize lipid oxidation during exercise, as evidenced by their lower Lipoxmax and MLOR.

Keywords: Women; Adipose tissue localization; Exercise; Metabolic fitness; $\text{Lipox}_{\text{max}}$

Abbreviations: A/LB, abdominal to lower-body; ANP, atrial natriuretic peptide; BMI, body mass index; CHO, carbohydrate; DXA, dual X-ray absorptiometry; FFA, free fatty acids; FFM, fat-free mass; FM, fat mass; H-A/LB, high abdominal to lower-body; L-A/LB, low abdominal to lower-body; MAP, maximum aerobic power; MLOR, maximum lipid oxidation rate; NW, normal-weight; SD, standard deviation; VCO_2, carbon dioxide production; VO_2, oxygen consumption; $\text{VO}_{2\text{max}}$, maximum oxygen consumption.

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1. Introduction

The exercise intensity that elicits the maximum lipid oxidation rate (MLOR) is termed $\text{Lipox}_{\text{max}}$ [1]. These two parameters are used to individualize training programmes for people with metabolic disorders wishing to maximize their lipid oxidation and decrease fat mass (FM) [1]. In addition, they are used to assess 'metabolic fitness', defined as aerobic fitness and skeletal muscle health [2]. $\text{Lipox}_{\text{max}}$ is influenced by training status, maturity, gender, and parameters of body composition such as total FM and fat-free mass (FFM) [1,3]. In fact, $\text{Lipox}_{\text{max}}$ occurs at a lower rate of maximum oxygen consumption ($\text{VO}_{2\text{max}}$) and is accompanied by a lower MLOR in obese compared with normal-weight (NW) subjects [1].

Adipose tissue localization is one factor affecting energy metabolism independently of total FM [4]. In NW and obese subjects, the abdominal fat depot is preferentially associated with metabolic disorders such as insulin resistance and dyslipidaemia, whereas peripheral FM is considered as a protective factor against cardiometabolic risk in the long term [5,6]. During exercise, greater increase in plasma free fatty acid (FFA) availability in obese women with lower-body fat compared with abdominal fat is indicative of greater stimulation of lipolysis in peripheral rather than central adipose tissue [7]. Our laboratory previously reported that NW women with a higher abdominal to lower-body (H-A/LB) FM ratio exhibited lowered lipid mobilization, oxidation and metabolic flexibility during submaximum exercise (45 min at 65% $\text{VO}_{2\text{max}}$) than NW women with a low abdominal to lower-body (L-A/LB) FM ratio [4].

Greater ability to maximize lipid oxidation rate, elicited at higher relative exercise intensities, is likely to reflect a profile of 'metabolic fitness' [2]. Thus, in terms of primary prevention, investigation of $\text{Lipox}_{\text{max}}$ and MLOR in NW women with specific adipose tissue distributions appears to be relevant for individualizing training programmes to improve metabolic effects and/or diagnose subjects with impaired lipid oxidation. Whereas the impact of total FM on $\text{Lipox}_{\text{max}}$ and MLOR has been well documented in studies comparing obese and NW subjects, little is known of the effects of adipose tissue distribution in women within the NW range. The aim of the present study was therefore to investigate the impact of low and high A/LB FM ratios on MLOR and $\text{Lipox}_{\text{max}}$ in NW women.

2. Methods

2.1. Population

Twenty-one recreationally active NW women (between 2 to 4 h/week of physical activity), with a mean age of 22.0 ± 0.6 years, were studied. All subjects were premenopausal and NW, with body mass index (BMI) values within the healthy weight range (BMI > 19.5 but < 25 kg.m^{-2}, 22.4 ± 2.5 kg.m^{-2}) and waist circumferences $\leq$80 cm. As there is no standard for the A/LB FM ratio in premenopausal lean women, ratios were calculated for the whole population ($n = 21$; 0.80 ± 0.1, range: 0.56–1.06). Based on the median (0.78), women were allocated to two groups: one with an L-A/LB FM ratio < 0.78 ($n = 11$; 0.68 ± 0.08, range: 0.56–0.77); and the other with an H-A/LB FM ratio > 0.78 ($n = 10$; 0.90 ± 0.1, range: 0.82–1.06). More detailed descriptions of the study population have been previously published [4].

The study was approved by the local ethics committee (*Comité de Protection des Personnes Sud Est VI*, AU818) and complied with the Helsinki declaration. Every woman signed an informed consent form to participate and attended the laboratory on two separate occasions.

2.2. Experimental design

Before inclusion, an initial screening interview and physical examination, including anthropometric measurements and body composition assessment, were performed. A second session was arranged to determine their $\text{Lipox}_{\text{max}}$, MLOR and $\text{VO}_{2\text{max}}$.

2.2.1. Abdominal to lower-body fat-free mass and fat mass ratios

Dual-energy X-ray absorptiometry (DXA) scans were visually analyzed by an experienced technician who delineated the region of interest between vertebral bodies L1 and L4 to determine abdominal FM (visceral and subcutaneous adipose tissue). The uppermost limit was set by a horizontal line going through the T12/L1 vertebral space, and the lowermost limit was set by a horizontal line going through the L4/L5 vertebral space. Lower-body FM was similarly determined using DXA scans, with the iliac crest as the uppermost limit of the lower limbs [4].

The A/LB FM ratio was calculated as: A/LB FM ratio = abdominal FM (g)/lower-body FM (g). Likewise, the A/LB FFM ratio was calculated from FFM located in the abdominal region of interest and lower-body FFM.

2.2.2. $\text{Lipox}_{\text{max}}$, MLOR and $\text{VO}_{2\text{max}}$

Exercise tests were performed on an electromagnetically braked cycle ergometer (Ergoline, Bitz, Germany). Respiratory gas exchanges (VO_2, VCO_2) were measured breath by breath through a mask connected to O_2 and CO_2 analyzers (Oxycon Pro-Delta, Jaeger, Hoechberg, Germany).

$\text{Lipox}_{\text{max}}$ expressed as a percentage of $\text{VO}_{2\text{max}}$, MLOR and carbohydrate (CHO) oxidation ($\text{mg.min}^{-1}.\text{kg FFM}^{-1}$) were determined in a fasting state during 6-min stages of graded exercise. The exercise test started at 20% of the predicted maximum aerobic power (MAP) with 10% MAP increments (up to 60% of MAP), and was followed by a rapid incremental test until $\text{VO}_{2\text{max}}$ and MAP were reached [1,8]. During the last minute of each stage (from the fifth to sixth minute), VCO_2 and VO_2 values were recorded and used to calculate the respective CHO and lipid oxidation rates [9].

The relationship between power output and lipid oxidation rates displays a bell-shaped curve. Smoothing of this curve enabled calculation of exercise intensity ($\text{Lipox}_{\text{max}}$) at the point of MLOR [8].