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Original article

Effects of a training program at the crossover point on the cluster of metabolic abnormalities and cardiovascular risk factors

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Abstract

The present study examined the effects of a training program at a special exercise intensity—the crossover point of substrate utilization (COP)—on the metabolic abnormalities and cardiovascular risk factors in obese women with metabolic syndrome (MetS). Eighteen postmenopausal obese women with MetS (age, 54.8 ± 8.4 years; height, 160 ± 6 cm) followed a 12-week training program consisting of three 45-minute sessions/wk on a cycle ergometer. The intensity imposed during the training sessions corresponded to COP. Before and after the training program, anthropometric, biological, and blood pressure data were collected and compared. After the training program, body mass (88.4 ± 12.3 kg vs. 85.7 ± 11.1 kg), fat mass (43.2 ± 4.8% vs. 41.8 ± 4.8% body mass), body mass index (34.3 ± 3.9 kg/m^2 vs. 33.2 ± 3.6 kg/m^2), and waist circumference (105 ± 10 cm vs. 100 ± 9 cm) were significantly lower ($p < 0.01$). Moreover, fasting plasma glucose was significantly lower after the training program (114 ± 20 mg/dL vs. 107 ± 15 mg/dL; $p = 0.02$) and the quantitative insulin-sensitivity check index was significantly higher (0.58 ± 0.08 vs. 0.61 ± 0.05; $p = 0.05$). A significant reduction in systolic blood pressure was also observed (141 ± 15 mmHg vs. 129 ± 11 mmHg; $p = 0.02$). After the program, the number of patients with fasting plasma hyperglycemia and arterial hypertension was significantly decreased by 54.4% and 44.4%, respectively, and the number of patients with MetS was nonsignificantly reduced by 22.2% ($p = 0.10$). The present study shows that a training program at COP is an efficient means to treat MetS.

Keywords: Glucose and lipid metabolism; Obesity; Physical exercise; Systolic blood pressure

Introduction

Metabolic syndrome (MetS) is characterized by a cluster of metabolic abnormalities and cardiovascular risk factors, including central obesity, dyslipidemia, insulin resistance, and arterial hypertension.[1] Although the prevalence of MetS in France appears to have been declining for some years,[2] it is still too high. Indeed, in the MONA LISA study, Wagner et al[2] examined the changes in the prevalence of MetS among the French and reported that in 2006 the prevalence was still elevated, at 23.1% and 15.1% in men and women, respectively.[2] Dealing with MetS is thus a major public health issue in France.

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Several authors have demonstrated that MetS increases not only the risk of cardiovascular diseases, but also mortality from cardiovascular disease and all causes.[3–5] It is thus essential to reduce its incidence, and several authors have supported physical exercise programs as a means to achieve this goal.[6–8] However, the expected beneficial effects seem to depend on the exercise intensity[9] and, as indicated by Pérez-Martin et al,[10] the optimal exercise intensity for obese patients with MetS has not yet been determined.

Overweight and obese patients have muscular metabolic abnormalities (e.g., metabolic abnormalities in the interactions between glucose and lipid metabolisms) that may need to be taken into account for individualized physical exercise prescription.[10] The crossover point of substrate utilization (COP), which can be determined from indirect calorimetry,[11–13] can be used to evaluate the abnormal interactions between the glucose and lipid metabolisms. According to the concept of Brooks and Mercier,[14] COP is the exercise intensity at which energy from carbohydrate-derived fuels predominates over energy from lipids. At this exercise intensity, approximately 70% of the energy derives from carbohydrate and 30% from lipids.[15] The notion of exercise intensity at the COP was initially conceived in the search to identify the optimal exercise intensity for obese patients with or without type 2 diabetes.[15,16] However, to our knowledge, no study has evaluated the effects of a training program at this special exercise intensity (i.e., COP) on the abnormalities defining MetS in obese women, even though some authors consider this exercise intensity as *optimal* for patients with metabolic abnormalities.[15,16]

The purpose of the present study was therefore to examine the effects of a training program at COP on the metabolic abnormalities and cardiovascular risk factors in obese women with MetS.

Materials and methods

Participants

Eighteen obese women [age, 54.8 ± 8.4 years; body mass, 88.4 ± 12.3 kg; height, 160 ± 6 cm; body mass index (BMI), 34.3 ± 3.9 kg/m^2] with MetS, which was diagnosed according to the criteria proposed by the National Cholesterol Education Program,[17] volunteered to take part in this study. All participants signed a consent form after being informed of the investigation purposes and procedures. This experiment was also approved by the local ethics committee for participants' protection in clinical research and the technical committee for clinical hospital research (CP 09-49).

Materials

Body mass (kg) and percentage of fat mass were assessed using a multifrequency bioelectrical impedance meter (BC-418 MA; Tanita, Arlington Heights, IL, USA).

The blood lipid concentrations (triglycerides, total cholesterol, and high-density lipoprotein cholesterol) were determined using an Architect C4000 system (Abbott, Rungis, France). The low-density lipoprotein cholesterol (LDL-C) concentrations were computed using Friedewald et al's[18] formula. The blood glucose concentrations were determined by an automated hexokinase method (AU5800 analyzer; Beckman-Coulter, Villepinte, France), and the glycosylated hemoglobin (HbA_{1c}) was measured by high-performance liquid chromatography (HLV-723 G7; Tosoh, Lyon, France).

To evaluate insulin resistance, blood insulin and leptin concentrations were measured using an immunoradiometric assay (Bi-INS-IRMA; Cisbio Bioassays, Codolet, France) and a radioimmunoassay assay (human leptin RIA kit; Millipore, Billerica, MA, USA), respectively.

Resting systolic blood pressure (SBP; mmHg) and diastolic blood pressure (DBP; mmHg) were measured using a noninvasive blood pressure monitor (Carescape V100; GE Healthcare, Chalfont Saint Giles, Bucks, UK).

Respiratory gas analysis was carried out through indirect calorimetry via a breath-by-breath system with an open-circuit metabolic card (Ergocard; Medisoft, Sorinnes, Belgium). This respiratory gas analysis system was calibrated in accordance with the manufacturer's guidelines.

The indirect calorimetry and the training sessions were conducted on an electromagnetically braked cycle ergometer (Excalibur Sport; Lode, Groningen, The Netherlands), which maintained the set power output by adjusting the resistance with variations in pedal rate.

Procedures

The purpose and procedures of the study were explained to the participants during the first session. Anthropometric data were also collected at this time. BMI was calculated as body mass (kg) divided by the square of height (m). An average of three readings, measured to the nearest cm, was taken.

Fasting blood samples were collected at rest (before the indirect calorimetry) from an antecubital vein after an overnight fast by an experienced nurse. The blood samples were coded and subsequently assayed. Insulin resistance was evaluated from the homeostasis model assessment of insulin resistance (HOMA-IR) index using the following equation[19]:

$$\text{HOMA} - \text{IR} = \text{insulinemia} \times \text{glycemia} \div 22.5$$

In this equation, the insulinemia and glycemia are expressed in μU/mL and mM, respectively. Moreover, to quantify insulin sensitivity, the quantitative insulin-sensitivity check index (QUICKI) was also calculated[20]:

$$\text{QUICKI} = 1 \div (\text{loginsulinemia} + \text{logglycemia})$$

In this equation, the insulinemia and glycemia are expressed in μU/mL and mM, respectively.

Resting SBP and DBP were determined from the left arm of the seated participant after 5 minutes rest. Three separate measurements were taken at 1-minute intervals, and the mean of the three readings was recorded.