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► To cite this version:

Marine Dupuit, Melanie Rance, Claire Morel, Patrice Bouillon, Bruno Pereira, et al.. Moderate-intensity continuous training or high-intensity interval training with or without resistance training for altering body composition in postmenopausal women. *Medicine and Science in Sports and Exercise*, 2020, 52 (3), pp.736-745. 10.1249/MSS.0000000000002162 . hal-02421652

HAL Id: hal-02421652

<https://uca.hal.science/hal-02421652>

Submitted on 15 Nov 2021

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1 **MICT or HIIT ± RT programs for altering body composition in postmenopausal women**

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31

32 **ABSTRACT**

33 **Purpose:** To compare body composition changes induced by moderate-intensity continuous
34 training (MICT), high-intensity interval training (HIIT), or HIIT + resistance training (RT)
35 programs (3 days/week, 12 weeks) in postmenopausal women with overweight/obesity, and to
36 determine whether fat mass reduction is related to greater fat oxidation (FatOx).

37 **Methods:** Participants (n=27) were randomized in three groups: MICT (40min at 55-60% of
38 peak power output, PPO), HIIT (60 x 8s at 80-90% of peak heart rate, 12s active recovery),
39 and HIIT + RT (HIIT + 8 whole-body exercises: 1 set of 8-12 repetitions). DXA was used to
40 measure whole-body and abdominal/visceral fat mass (FM) and fat-free mass (FFM). FatOx
41 was determined at rest, during a moderate-intensity exercise (40min at 50% of PPO), and for
42 20 minutes post-exercise, before and after training.

43 **Results:** Overall, energy intake and physical activity levels did not vary from the beginning to
44 the end of the intervention. Body weight and total FM decreased in all groups over time, but
45 significant abdominal/visceral FM losses were observed only in HIIT and HIIT + RT groups.
46 When expressed in percentage, total FM, FFM, and muscle mass were significantly modified
47 only by HIIT + RT training. FatOx did not change at rest, but increased similarly in the three
48 groups during and after exercise. Therefore, the HIIT-induced greater FM loss was not related
49 to higher FatOx during or after exercise.

50 **Conclusions:** MICT or HIIT \pm RT could be proposed to non-dieting postmenopausal women
51 with overweight/obesity to decrease weight and whole-body FM. The HIIT programs were
52 more effective than MICT in reducing abdominal/visceral FM. RT addition did not potentiate
53 this effect, but increased the percentage of muscle mass.

54

55 **Key words:** Menopause, (intra)-abdominal fat mass, high intensity interval training, resistance
56 training, fat oxidation rate.

57

58

59 INTRODUCTION

60 In women, the incidence of obesity, type 2 diabetes and cardiovascular diseases (CVD)
61 significantly increases after menopause and is related to an increase of fat mass (FM) (1–3),
62 loss of fat-free mass (FFM) (especially muscle mass) (3), and body fat distribution alterations
63 (1, 4). The increase of subcutaneous and particularly intra-abdominal FM (*i.e.*, visceral FM)
64 after menopause partly explains the higher CVD risk in postmenopausal women (5).

65 Menopause is associated with a decrease of the resting metabolic rate (RMR) (6) and fat
66 oxidation (FatOx) during physical activity (7, 8) and a lower total energy expenditure (EE) (8,
67 9). Although literature data show that the diet and physical activity combination promotes
68 longer-term weight and/or FM loss, exercise alone also might have positive effects, particularly
69 on subcutaneous and intra-abdominal FM (10), if the training program is well supervised and
70 if the EE leads to a negative energy balance (11).

71 The American College of Sports Medicine (ACSM) has recommended moderate intensity
72 continuous training (MICT) in patients with obesity for losing weight and/or FM (11). This
73 strategy is efficient in pre- and post-menopausal women with overweight or obesity (12, 13).
74 Currently, high-intensity interval training (HIIT), which includes repeated bouts of high
75 intensity effort followed by varied recovery times (14), is considered a time-efficient and safe
76 strategy to reduce total FM and particularly subcutaneous and intra-abdominal FM in people
77 with overweight/obesity (15). Our group demonstrated that in postmenopausal non-dieting
78 women with type 2 diabetes, HIIT is more effective for reducing central obesity than MICT,
79 and can be proposed as an alternative exercise program in this population (16). Resistance
80 training (RT) does not enhance weight loss, but may increase FFM and decrease FM, and is
81 associated with health risk reduction (11). Although several previous publications have focused
82 on RT or MICT + RT effects on body composition (17, 18), only few randomized trials
83 compared the impact of a combined HIIT + RT program in overweight/obese adults (19, 20),

84 and no study has been performed on postmenopausal women. The effects of HIIT \pm RT
85 programs on fat mass losses may be partly due to the increase of RMR, total EE and FatOx
86 (21). No study has thoroughly evaluated the impact of HIIT or HIIT + RT on these parameters
87 in postmenopausal women, but limited post-training muscle mass gain in the female population
88 could alter these adaptations (22).

89 Therefore, the aim of this study was to compare the effects of 12-week MICT, HIIT and HIIT
90 + RT programs on body composition and FatOx in postmenopausal women with
91 overweight/obesity. We hypothesized that compared with the traditional MICT, HIIT programs
92 could be more efficient in reducing whole-body and abdominal/visceral FM and to favor
93 FatOx, and that HIIT + RT, by also improving FFM and RMR, could offer the best benefits.

94

95 **METHODS**

96

97 The study was approved by the relevant ethics committee (Comité de Protection des Personnes
98 Sud Est VI, CPPAU1303) and was registered on ClinicalTrials.gov via the Protocol
99 Registration System (ClinicalTrials.Gov: NCT 03357016). After receiving detailed
100 information on the study objectives and protocol, all participants signed a written informed
101 consent.

102

103 **Participants**

104 Thirty-five women (mean age 62.4 ± 6.7 yr) were recruited according to the following inclusion
105 criteria: postmenopausal women, body mass index (BMI) $>25 \text{ kg/m}^2$ and $\leq 40 \text{ kg/m}^2$, and stable
106 eating habits and physical activity for at least 3 months. Non-inclusion criteria were: medical
107 contraindications to intense physical activity, painful joints, and taking hormone replacement
108 therapy. Finally, 30 postmenopausal women with overweight/obesity were selected for the

109 three 12-week interventional programs (Fig. 1). None of the participants had history of chronic
110 arterial or respiratory disease, CVD, or endocrine disorders. All participants reported low levels
111 of physical activity, based on the Global Physical Activity Questionnaire (GPAQ) results (23).
112 Upon recruitment, participants were randomly assigned to an exercise modality [HIIT ($n = 10$),
113 MICT ($n = 10$), HIIT + RT $n = 10$]. A familiarization period of at least 10 days allowed
114 participants to get accustomed with the exercise equipment before training.

115

116 **EXPERIMENTAL DESIGN**

117

118 **Anthropometric and body composition measurements.** Body weight was measured to the
119 nearest 0.1 kg on a Seca 709 scale (Balance Seca 709, France) in fasting conditions, with the
120 subjects wearing only underwear. Height was measured to the nearest 0.5 cm with a wall-
121 mounted stadiometer. Body mass index (BMI) was calculated as body weight (kg) divided by
122 the square of height (m^2). Waist circumference (cm) was measured midway between the last
123 rib and upper iliac crest, and hip circumference at the level of the femoral trochanters. Both
124 measures were taken in standing position with a measuring tape. Sagittal abdominal diameter
125 (supine abdominal height) was measured with a Holtain–Kahn abdominal caliper (Holtain
126 Limited, Crymych, Pembrokeshire, UK) to the nearest mm in the sagittal plane at the level of the iliac
127 crests (L4–L5) during normal expiration, with the subject lying supine on a firm bench with
128 knees bent. Abdominal skinfold thickness was measured at four different sites (at 15 cm and 7
129 cm to the right and left of the navel) with a Harpenden Skinfold Caliper (Mediflex Corp., Long
130 Island, NY, USA), and the mean subcutaneous abdominal skinfold thickness was then
131 calculated (16). The same experienced investigator took all anthropometric measurements at
132 baseline and after 12 weeks of training.

133

134 **Adipose and fat-free mass tissue localization.** Total body and regional FM as well as FFM
135 (expressed as kg and % of body mass) were measured with a dual-energy X-ray absorptiometry
136 (DXA) scanner (QDR-4500A, Hologic, Inc., Marlborough, MA, USA). Two regions of interest
137 were manually isolated and analyzed by an experienced technician: the area from L1–L2 to the
138 pubic rami to determine the total abdominal FM (kg), and the area from the iliac crest to the
139 feet to calculate the lower-body FM (kg). The same operator performed all analyses. Total
140 visceral FM (kg) was estimated from the total abdominal FM on DXA, mean subcutaneous
141 abdominal skinfold thickness and abdominal height, as previously described (16).

142

143 **Preliminary visit-maximal exercise testing.** VO_{2max} was measured during a graded
144 exhaustive exercise test on a cycle ergometer (Ergoline, Bitz, Germany). After a 3min warm-
145 up at 30 W, power output was increased by $10\text{ W}\cdot\text{min}^{-1}$ until the participant's exhaustion (the
146 test lasted between 10 and 15 minutes after warm-up). Participants were strongly encouraged
147 by the experimenters throughout the test to perform a maximal effort. Respiratory gases (VO_2
148 and VCO_2) were measured breath-by-breath through a mask connected to O_2 and CO_2 analyzers
149 (Oxycon pro-Delta, Jaeger, Hoechberg, Germany). VO_{2max} was determined as the highest
150 oxygen uptake during a 15s period. Ventilatory parameters were averaged every 30s. Heart
151 activity was monitored by ECG throughout the test, and heart rate (HR) recorded continuously.
152 The achievement of VO_{2max} criteria were: 1) oxygen uptake reaching a plateau with increasing
153 work rate; 2) RER values higher than 1.1; and 3) peak heart rate (PHR) within 10% of the age-
154 predicted maximal values (24). The peak power output (PPO), expressed in watts or $\text{watts}\cdot\text{kg}^{-1}$,
155 was considered the highest power measured at VO_{2max} .

156

157 **Training programs.**

158 We made the choice to have similar energy expenditure (EE) between MICT and HIIT sessions
159 and to have the same session duration between MICT and HIIT + RT, because lack of time is
160 a barrier to exercise for people with overweight/obesity. Thus, before the beginning of the
161 training programs, the EE induced by a HIIT session (20 min duration) was measured in four
162 subjects using a Metamax 3B apparatus (Matsport, France), and the time needed to spend the
163 same energy was calculated during the MICT session. The mean EE spent for each HIIT or
164 MICT session was 180 ± 22 kcal and the time required for a MICT session was established to
165 40 minutes. Therefore, each HIIT + RT session lasted 40 minutes (20 min of HIIT and 20 min
166 of RT).

167 Participants performed three exercise sessions per week for 12 weeks (total = 36 sessions).
168 Sessions were generally in the morning on Monday, Wednesday and Friday, to allow a
169 sufficient recovery period, and were supervised by an experienced physical activity instructor.
170 Each session included also 5 min warm-up and 2 min cool-down periods, in addition to the
171 formal training.

172

173 **Moderate-intensity continuous training (MICT).** The MICT session consisted of 40min at
174 55-60% of the participant's PPO performed continuously on a C-Max Club Fitness bike.
175 During the first 6 weeks, the intensity was set at 55% of the PPO and was increased to 60% for
176 the last 6 weeks to take into account the participants' aerobic fitness improvement. Each
177 participant's resistance, pedal cadence (50-70 rpm), and power (watts) were controlled to reach
178 the expected intensity.

179

180 **High-intensity interval training (HIIT).** The HIIT training program was based on the
181 protocol by Maillard et al. (2016) (16), an attractive and feasible cycling program for
182 postmenopausal women with overweight/obesity. The HIIT protocol consisted of repeated

183 cycles of sprinting/speeding for 8s followed by slow pedaling (20–30 rpm) for 12s on a
184 WattBike pro Concept2 (with a freewheel and a double air and magnetic braking system).
185 Resistance was very low to facilitate acceleration and limit bicycle-wheel inertia. Resistance
186 was controlled to reach ~ 80% of each participant's PHR during the 20min session. All
187 participants could complete the full 20min exercise program at this intensity after two or three
188 sessions. HR was continuously monitored (A300, Polar, Finland) to control the intensity.
189 Overall, the mean intensity during a HIIT session corresponded to $85 \pm 4\%$ of PHR.

190

191 **High-intensity interval training and resistance training (HIIT + RT).** HIIT was always
192 performed before RT to normalize the concurrent training effects (25). The HIIT session was
193 the same as for the HIIT alone group. The upper and lower body muscular strength was
194 measured using the one-repetition maximum (1 RM) method with bench press and leg press
195 exercises on Universal™ weight machines, as previously described (26). Briefly, a warm-up
196 of 5–10 repetitions at 40–60% of the perceived maximum was performed, followed by 3–5
197 repetitions at 60–80% of the perceived maximum. Three to four subsequent attempts were then
198 made to determine the 1 RM for each exercise. Rest periods (3-5min) were introduced between
199 lifts to ensure optimal recovery.

200 The RT program included two different training circuits with ten exercises/each and was based
201 on the program by Marx et al. (27). Circuit 1 included leg press, bench press, knee extension,
202 cable row, dumbbell calf raise, elbow flexion, abdominal muscle, triceps exercises with upper
203 pulley, plank and bum exercises. Circuit 2 included knees extension, pullover, leg press, side
204 raise with dumbbells, dumbbell calf raise, triceps exercises with upper pulley, hip thrust, chin
205 rowing, and plank to upright row. Participants performed a single-set circuit, with a load of 8–
206 12 repetitions at around 80% of 1RM, with 1- to 1.5min rest period between exercises. The
207 workouts were individually supervised by the same certified personal trainer. When

208 participants achieved more than 12RM, the load was adjusted to remain in the planned intensity
209 zone. Participant alternated between circuits every 3 weeks to minimize boredom and to create
210 some variation in the exercise choice.

211

212 **Resting metabolic rate (RMR) and substrate oxidation.** Subjects arrived at the laboratory
213 at 7.30 am after overnight fast (12h). Participants were asked to eat a similar dinner for the pre-
214 and post-training session the evening before, and to avoid any kind of strenuous exercise the
215 day before. The experiment was conducted in a ventilated room at a temperature of 19–20°C.
216 RMR and substrate oxidation were determined from respiratory gases using a Metamax 3B
217 apparatus (Matsport, France). Carbohydrate oxidation and FatOx were measured at rest, during
218 moderate-intensity prolonged exercise, and during the recovery period. Exercise consisted in
219 40min of cycling at 55% of their PPO determined before and after training on a cycle ergometer
220 (Ergoline, Bitz, Germany). Cadence was maintained between 60 and 70 rpm. HR was
221 continuously monitored (A300, Polar, Finland). Resting gas exchange data were recorded for
222 10 minutes, with the subject sitting on the bicycle. The last 2min of gas exchange data from
223 each stage were averaged to calculate VO_2 and VCO_2 that were then used to determine the
224 RER ($RER = VCO_2/VO_2$). Recording was continued during the recovery period for 20 minutes.
225 RMR assessment was considered valid in the presence of a minimum of 10min of steady state
226 with less than 10% of fluctuations in oxygen consumption (VO_2). RMR ($kcal.day^{-1}$) was
227 calculated using the Weir equation (28), and substrate oxidation ($g.min^{-1}$) was calculated using
228 the Frayn's equations (29), as follows:

229 - $RMR = [(3.941 \times VO_2) + (1.1106 \times VCO_2)] \times 1440$

230 - Carbohydrate (CHO) oxidation = $[(4.55 \times VCO_2) - (3.21 \times VO_2)]$

231 - FatOx = $[(1.67 \times VO_2) - (1.67 \times VO_2)]$

232

233 **Physical activity and dietary assessments.** Participants were asked to maintain their normal
234 levels of physical activity during the 12-week study period. Their usual weekly level of
235 physical activity was determined at baseline and after 12 weeks using the French version of the
236 GPAQ (23). They were also asked to maintain their normal eating habits for the study period.
237 At baseline and at week 12 of training, each participant filled in a 7-day food-intake diary that
238 was evaluated by a dietician using a nutrition analysis software program (Nutrilog®, Marans,
239 France).

240

241 **Biochemical Assays.** Blood samples were taken the week before starting the training (pre-
242 intervention) and then 2–4 days after the last exercise session (post-intervention), depending
243 on the participants' availability and to avoid any potential effect of the last exercise session on
244 the results. After overnight fasting, a cannula was inserted in the antecubital vein, and whole
245 blood was collected in EDTA- and fluoride-containing vacutainers tubes. The plasma
246 concentration of total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and
247 triglycerides (TG) was immediately measured, using a Synchron Clinical System UniCel Dx-C
248 analyzer (Beckman Coulter, Brea, CA, USA) and a cholesterol oxidase method for TC (CHOL
249 reagent), a direct homogeneous method for HDL-C (HDL-D reagent), and a lipase/glycerol
250 kinase method for TG (GPO reagent). The low-density lipoprotein cholesterol (LDL-C)
251 fraction was indirectly quantified using the equation described by Friedewald et al. (30).
252 Plasma glucose concentration was immediately determined using the hexokinase method
253 (UniCel Dx-C analyzer, Synchron). Plasma insulin concentration was measured by enzyme-
254 linked immunosorbent assay from Sigma-Aldrich Insulin Elisa kit (Paris, France). HbA1c
255 values were evaluated with a high-performance liquid chromatography (HPLC) Variant II
256 analyzer equipped with the new 270-2101 NU Kit (Bio-Rad Laboratories, Hercules, CA, USA).

257 The HOMA-IR index was calculated using the formula: $\text{HOMA-IR} = [\text{Fasting glucose}$
258 $(\text{mmol.L}^{-1}) \times \text{Fasting insulin } (\mu\text{U.mL}^{-1})] / 22.5$.

259

260 **Statistical analyses.** Before the study start, the sample size required for a statistical power of
261 80% was calculated based on previous results on FM loss after HIIT training in women (31).
262 Based on a two-sided type I error of 5%, a minimum difference of 1.5 ± 0.88 kg, as described
263 by Tremblay et al. (32), for FM loss could be detected with seven women per group. Our sample
264 was increased to ten women per group at the beginning of the intervention to take into account
265 participants lost to follow-up.

266 All statistical analyses were carried out with the STATISTICA version 12.00 software (StatSoft
267 Inc., Tulsa, OK, USA). Data are presented as the mean \pm standard deviation (SD). The data
268 normal distribution was tested using the Kolmogorov–Smirnov test, and the homogeneity of
269 variance was tested with the F-test. Data were log-transformed, when appropriate, prior to
270 statistical analyses. Two-way analysis of variance (ANOVA) with repeated measures was used
271 to determine group and time effects, and group \times time interactions. When a significant effect
272 was found, post-hoc multiple comparisons were performed using the Newman-Keuls test. The
273 effect size was reported when significant main or interaction effects were detected. The effect
274 size was assessed using the partial eta-squared (η^2) and ranked as follows: ~ 0.01 = small effect,
275 ~ 0.06 = moderate effect, ≥ 0.14 = large effect (33). Baseline values and changes between
276 baseline and the study end [delta change: $(12 \text{ weeks} - \text{baseline} / \text{baseline}) \times 100$] were also
277 compared among groups, using one-way ANOVA. Differences with a P-value ≤ 0.05 were
278 considered statistically significant.

279

280 **RESULTS**

281

282 **Participants' Characteristics.** Of the 30 postmenopausal females randomized in the three
283 training groups (n=10/group), 27 were retained for the analysis (n=3 left the study for different
284 reasons listed in Fig. 1). At baseline, the mean age was not significantly different among groups
285 (MICT: 67.1 ± 7.2 y; HIIT: 59.9 ± 5.9 y; HIIT + RT: 61.1 ± 5.4 y) as well as total body weight
286 (MICT: 80.4 ± 7.1 kg; HIIT: 81.6 ± 12.7 kg; HIIT + RT: 75.6 ± 8.9 kg) and total FM (MICT:
287 30.6 ± 5.3 kg; HIIT: 27.6 ± 10.7 kg; HIIT + RT: 28.1 ± 5.8 kg) (Table 1). The participants'
288 compliance with the training program was $97\% \pm 1\%$. No adverse event was reported during
289 testing or training in any group.

290

291 **Habitual Energy Intake and Energy Expenditure.** Physical activity levels (GPAQ scores)
292 were comparable between pre- and post-training in all groups. For all participants, the daily
293 energy intake and the percentage of energy contribution from macronutrients did not
294 significantly change during the intervention period. No significant dietary intake difference
295 was observed in the three groups at baseline and after 3 months (mean values: $1563 \text{ kcal} \pm 276$
296 pre-intervention vs $1557 \text{ kcal} \pm 255$ post-intervention).

297

298 **Aerobic Fitness.** $\text{VO}_{2\text{max}}$ ($\text{ml}\cdot\text{min}\cdot\text{kg}^{-1}$) and PPO (watts or $\text{watts}\cdot\text{kg}^{-1}$) were not different in the
299 three groups at baseline (Table 1). Overall, aerobic fitness ($\text{VO}_{2\text{max}}$ and PPO) significantly
300 increased after the 12-week intervention (time effect, $p < 0.0001$, $\eta^2 = 0.71$). A group effect was
301 noted concerning $\text{VO}_{2\text{max}}$ ($\text{ml}\cdot\text{min}\cdot\text{kg}^{-1}$) and PPO (when expressed in watts, but not in $\text{watts}\cdot\text{kg}^{-1}$)
302 with lower values in the MICT group than in the HIIT and HIIT + RT groups ($p = 0.042$, η^2
303 $= 0.24$).

304

305 **Anthropometric Measurements and Whole Body Composition.** Overall, body weight (kg),
306 total FM (kg) and waist and hip circumferences (cm) were significantly decreased after the 12-

307 week intervention (time effect, $p=0.02$, $\eta^2 = 0.21$; $p=0.002$, $\eta^2 = 0.34$; $p=0.01$, $\eta^2 = 0.44$; $p =$
308 0.001 , $\eta^2 = 0.37$, respectively) (Table 1). When the absolute values were expressed in
309 percentage (%), total FM decreased and FFM and muscle mass increased only in the HIIT +
310 RT group ($p = 0.02$, $\eta^2 = 0.20$). The percentage of total FM loss (kg) was higher (but not
311 significant, $p=0.07$) in the HIIT and HIIT + RT groups than in the MICT group ($-3.06 \% \pm 4.2$,
312 $-4.43 \% \pm 3.1$ and $-0.05 \% \pm 3.9$ respectively), but with a large size effect ($\eta^2 = 0.19$) (Fig. 2).

313

314 **Abdominal and Visceral Fat Mass.** Baseline total abdominal (kg) and visceral FM (kg) were
315 similar in the three groups. At the end of the training period, total abdominal FM (kg) was
316 significantly reduced only in the HIIT and HIIT+RT groups (group \times time interaction; p
317 <0.008 , $\eta^2 = 0.48$) (Table 1). When expressed as delta change values, abdominal and visceral
318 FM changes were reduced only in the HIIT and HIIT + RT groups and were significantly
319 different from MICT (Fig. 2). No significant difference was noted after training between the
320 HIIT and HIIT + RT groups.

321

322 **Resting Metabolic Rate, Substrate Oxidation and Energy Expenditure.** None of the
323 training modes altered RMR ($\text{kcal}\cdot\text{day}^{-1}$) and substrate oxidation at rest (Table 2). Overall, all
324 training programs increased FatOx during moderate intensity exercise (expressed as percentage
325 of EE or $\text{g}\cdot\text{min}^{-1}$) and during the recovery period (time effect, $p < 10^{-4}$, $\eta^2 = 0.47$) (Fig. 3).
326 Concomitantly, carbohydrate oxidation decreased. No group effect was noted. EE (kcal) during
327 exercise and during recovery did not change between pre- and post-intervention in any group.

328

329 **Metabolic Profile.** The lipid profile and glycemic parameters at baseline and after the 12-week
330 intervention are listed in Table 3. Overall, plasma TG levels decreased after the intervention
331 (time effect, $p=0.02$, $\eta^2 = 0.22$), without any group effect or group \times time interaction. Whatever

332 the training mode, TC, HDL-C, and LDL-C levels did not change. Glycemia, insulinemia,
333 HbA1c, and HOMA-IR were not modified by the intervention.

334

335

336 **DISCUSSION**

337

338 The aim of this study was to compare the body composition and FatOx changes induced
339 by a 12-week MICT, HIIT or HIIT + RT intervention in postmenopausal women with
340 overweight or obesity. All three modalities improved body composition (body weight, FM
341 loss), but HIIT (alone and with RT) led to a greater percentage of FM loss. Moreover,
342 abdominal and visceral FM (%) were only reduced in the HIIT and HIIT + RT groups, and
343 were significantly different from MICT. Our results also indicate that HIIT-induced total or
344 (intra)-abdominal FM losses were not related to higher FatOx during moderate intensity
345 exercise or during the 20min post-exercise period.

346

347 Physical activity is recommended in the framework of weight management programs to prevent
348 weight gain, to induce weight loss, and to avoid weight regain after weight loss. Indeed,
349 exercise on its own may generate significant weight and FM loss (10) with beneficial effects
350 on health (11). Furthermore, (intra)-abdominal FM reduction is of interest due to FM
351 association with CVD risks (34). The current international guidelines generally suggest
352 endurance training as the best strategy for weight loss and FM reduction in both sexes. In the
353 last position stand by the American College of Sports Medicine (ACSM) (11), moderate
354 intensity physical activity (between 150 and 250 min.week⁻¹) is recommended for preventing
355 weight gain, and more exercise for providing significant weight loss. Recent evidence suggests
356 that HIIT can be a time-efficient strategy to decrease whole-body and (intra)-abdominal FM in
357 sedentary individuals with overweight/obesity (15, 35). In their meta-analysis, Wewege et al.

358 evaluated the effect of HIIT and MICT on weight and FM changes in individuals with
359 overweight and obesity (35). Their found that both HIIT and MICT programs improved FM
360 and waist circumference, even in the absence of body weight changes. They also showed that
361 HIIT and MICT were similarly efficient, but that HIIT training required ~40% less time
362 commitment. The meta-analysis by Maillard et al. (2018) focused on HIIT effects on whole-
363 body and (intra)-abdominal FM loss in individuals with normal weight and with
364 overweight/obesity. The authors confirmed that HIIT is a time-efficient strategy to decrease
365 not only whole-body FM, but also abdominal and visceral FM (15). On the other hand, results
366 were less convincing in postmenopausal women. Indeed, only three studies have evaluated the
367 effects of HIIT on body composition in this population (16, 36, 37), and only one showed a
368 positive effect of HIIT on total and (intra)-abdominal FM loss (16). To our knowledge, no
369 study is available on the effects of HIIT + RT on body composition in postmenopausal women.

370

371 Our results indicate that MICT, HIIT and HIIT + RT programs (3 sessions.week⁻¹, 12 weeks)
372 decrease body weight, waist and hip circumferences and whole-body FM in postmenopausal
373 women with overweight/obesity. This confirms the conclusions of the two previously
374 mentioned meta-analyses. However, when expressed as delta change values (post-pre/pre ×
375 100), our study showed that in post-menopausal women, FM losses were significantly higher
376 in the HIIT and HIIT + RT (-3.1 kg and -4.4 kg, respectively) than in the MICT group (-0.1
377 kg). ~~Conversely, the meta-analysis by Weewege et al. found that HIIT and MICT were similarly~~
378 ~~effective (35).~~ Compared with the three studies on postmenopausal women and HIIT-induced
379 body composition changes, our results are similar to those of the ~~meta-analysis~~ study performed
380 by Maillard et al. (16), but in contradiction with those reported by Mandrup et al. (36) and
381 Steckling et al. (37) who did not detect any HIIT effect on total FM. These discrepancies could
382 be explained by the different exercise modalities (14). Indeed, we used the same HIIT protocol

383 as Maillard et al. (16) (*i.e.*, 60 x 8s at 80-90% of PHR, 12s active recovery), whereas Mandrup
384 et al. and Steckling et al. used three blocks of varying intervals with multiple periods of
385 maximum performance for 1h (36), and 4x 4 min 90%HRmax + 3 min active recovery 70
386 HRmax (37), respectively. Furthermore, in the study by Mandrup et al. (36), women did not
387 have obesity, and it is well known that HIIT-induced FM loss is more effective in individuals
388 with obesity (15). Finally, Mandrup et al. and Steckling et al. did not evaluate dietary intakes
389 and/or physical activity levels during their interventions. A spontaneous increase of energy
390 intake or a decrease in total energy expenditure could explain the absence of effect on FM in
391 these works. In our study, the levels of physical activity and total energy intake remained
392 unchanged, strengthening our conclusion that HIIT is an efficient strategy to lose body weight
393 and FM in postmenopausal women with overweight/obesity.

394 At baseline the plasma values were within the normal ranges, and this may explain why training
395 did not modify the lipid profile and glucose homeostasis. Although our participants did not
396 have hypertriglyceridemia (defined as a TG concentration higher than 150 mg.dL⁻¹ or 1.7
397 mmol.L⁻¹) and higher risk of cardiovascular disease (38), we observed a decrease of TG levels
398 over time, but without difference between groups.

399 Our results also demonstrate that only HIIT and HIIT + RT significantly decreased (intra)-
400 abdominal FM (*i.e.*, subcutaneous FM from the abdomen and visceral FM). It is worth noting
401 that despite exercising almost half the time compared with the MICT group (20min *vs.* 40min),
402 women in the HIIT group lost 7.4% of total abdominal FM and 3.2% of visceral FM.
403 Conversely, no change was observed in the MICT group, and the total abdominal FM loss in
404 the HIIT + RT group was not higher than in the HIIT group, despite the longer exercise time
405 (40min). These results confirm the meta-analysis by Maillard et al. (15) showing that HIIT
406 significantly reduces abdominal ($p = 0.007$) and visceral ($p = 0.018$) FM, with no difference
407 between men and women.

408

409 The mechanisms underlying HIIT-induced total and (intra)-abdominal FM loss are still not
410 completely elucidated, but might partly be explained by significant higher lipolysis during
411 exercise and greater post-exercise total and abdominal fat oxidation (15). These adaptations are
412 probably facilitated by the higher excess post-exercise oxygen consumption observed after
413 exercises performed above 75% VO_{2max} (39). Indeed, lipid oxidation decreases above 40–
414 50% VO_{2max} , but higher intensities still induce significant lipolysis from β -adrenergic receptors
415 stimulation. Thus, HIIT can increase plasma FFA levels during exercise and then promote
416 greater fat oxidation during the recovery period. This adaptation could explain why people who
417 are engaged in regular vigorous physical activities are less fat than those who never take part
418 in such activities (32). After an acute session of HIIT, MICT or High-Intensity Resistance
419 Training (HIRT) performed by recreationally active women, Wingfield et al. (40) demonstrated
420 lower RER in the HIIT than the MICT and HIRT groups (30min and 60min of recovery),
421 confirming the higher post-exercise fat oxidation in HIIT.

422 It is now recognized that higher amount of visceral/abdominal fat is lost in HIIT compared with
423 MICT programs (15). As the content of β -adrenergic receptors is higher in intra-abdominal
424 than in subcutaneous adipose tissue (41), the higher HIIT-induced sympathetic nervous system
425 stimulation could explain the larger reliance on visceral FM. Moreover, visceral adipose tissue
426 is characterized by smaller adipocytes, greater lipolytic activity, and lower responses to the
427 antilipolytic effects of insulin compared with subcutaneous depots (42). Lastly, subcutaneous
428 or (intra)-abdominal FM losses may also be facilitated by HIIT-induced PGC1- α transcription
429 stimulation. Shirvany and Arabzadeh (43) recently proposed that the increase of PGC1- α
430 expression in muscle tissue may induce endocrine effects on adipose tissue and adipokines,
431 leading to higher fat oxidation. Altogether, this may explain why HIIT promotes greater
432 abdominal and visceral FM losses compared with the traditional MICT.

433

434 We also made the hypothesis that HIIT, compared with MICT, might increase fat oxidation at
435 rest and during free-living physical activities (walking, cycling, gardening...) by altering
436 metabolic flexibility. To test this hypothesis, we determined fat oxidation before and after the
437 training period at rest and during a moderate-intensity exercise (40min at 50% of PPO) and
438 during the 20min recovery time. None of the training modes altered RMR ($\text{kcal}\cdot\text{day}^{-1}$) and
439 substrate oxidation at rest. As expected, FatOx levels were significantly increased, but without
440 any difference among the three groups. The mean FatOx change measured after training (~
441 +32%) was similar to what reported by other studies using the same amount of activity (12
442 weeks/3 times per week). For example, Talanian et al. (44) showed an increase of 36% in
443 whole-body fat oxidation during a 1 hour-cycling performed at 60% $\text{VO}_{2\text{peak}}$ after a HIIT
444 program (two weeks, 7 sessions including 10 x 4min at 90% $\text{VO}_{2\text{peak}}$ with 2min recovery) in
445 young sedentary women with overweight or obesity. Our study, which was the first to compare
446 FatOx in postmenopausal women with overweight/obesity at rest, during moderate intensity
447 physical activity and during the recovery period after three different training programs, did not
448 find a greater impact of HIIT on metabolic flexibility and no correlation appeared between
449 FatOx and total or (intra)-abdominal FM loss. Thus, the hypothesis of a greater FatOx after
450 HIIT programs was not verified in postmenopausal women and cannot explain the larger
451 adipose tissue reduction.

452 Our study also examined the effects of HIIT combined with RT on body composition
453 in postmenopausal women. An increase of muscle mass after HIIT + RT program might
454 enhance RMR and therefore, the 24h EE. The 24h EE increase could favor in turn body FM
455 loss because a part of the EE is provided through lipid oxidation. The recent meta-analysis by
456 Sabag et al. (45) shows that HIIT + RT leads to similar muscle mass gain (hypertrophy) as RT
457 alone. Furthermore, concurrent HIIT and RT does not negatively affect muscle mass gain.

458 However, these results should be considered with caution because this meta-analysis concerned
459 263 young participants (18-34 years) among whom only 33 were inactive or untrained. Thus,
460 these conclusions are probably more adapted to young athletes than to individuals with
461 overweight/obesity.

462 In our study, loss of total and of (intra)-abdominal FM was not significantly different in the
463 HIIT and HIIT + RT groups. In fact the lack of muscle mass gain (kg) in the HIIT + RT group
464 could explain this finding. Indeed, the duration or volume and/or intensity of the RT protocols
465 in our study could have been insufficient to induce a significant increase of muscle mass. It is
466 not possible to compare our results with the literature because this is the first study dealing
467 with HIIT + RT effects on body composition in postmenopausal women. However, three
468 studies on endurance training + RT have been performed. For example, Martin et al. (46) did
469 not find any effect of HIIT or combined training (aerobic + resistance exercises) on total body
470 fat (%) and muscle mass index ($\text{kg}\cdot\text{m}^{-2}$) in postmenopausal women after a 12-week
471 intervention. Davidson et al. found greater total, abdominal and visceral FM losses following
472 a 6-month MICT + RT program (30min walking at 65-70% VO_2max + 9 resistance exercises,
473 3 d·wk⁻¹) compared with MICT or RT alone in older adults with obesity (42). These
474 adaptations were associated with significant skeletal muscle gain, which may confirm the
475 potential link between muscle mass gain and FM loss after RT. Finally, Nunes et al. (47)
476 demonstrated a decrease of whole-body FM (-0.3%) after a 12-week MICT + RT program (60
477 min of walking at 70% of PHR and resistance exercises at 70% of one repetition maximum; 3
478 d·wk⁻¹) in postmenopausal women. However, they did give any information on FFM and
479 muscle mass changes. Additional studies using different RT modalities (duration, volume,
480 intensity) are probably needed to determine whether RT alone or together with HIIT might
481 promote muscle mass gain in postmenopausal women, leading to significant FM loss.

482

483 One of the limitations of this study concerns the groups tested. Indeed, it is difficult to conclude
484 about a potential effect of HIIT + RT without knowing whether the RT intervention alone could
485 induce positive adaptations. Thus, to determine whether the RT intervention can favor muscle
486 adaptations, it would have been interesting to add also a RT group. We decided to have the
487 same session duration for the MICT and HIIT + RT programs since a lack of time has been
488 cited as a barrier for overweight/obese people. This limited the amount of RT work and this
489 might not have been enough to induce muscle mass gain, especially in women. Furthermore,
490 we can also hypothesize that the HIIT + RT combination may alter muscle adaptations by
491 inducing molecular pathway interferences between training modalities. Indeed, it has been
492 suggested that endurance training performed before RT negatively affects RT adaptations
493 through inhibition of the AKT-mTOR pathway activation by AMPK (25). Finally, a last group,
494 MICT+ RT, might induce different adaptations but appeared to us less attractive due to the
495 duration of the session (≥ 1 hour).

496

497 In conclusion a 12-week cycling MICT or HIIT \pm RT program (3 sessions.week⁻¹) can
498 be proposed to non-dieting postmenopausal women with overweight/obesity to decrease
499 weight and whole-body FM. HIIT programs seems more successful in reducing (intra)-
500 abdominal FM than the traditional moderate continuous training. As the level of subcutaneous
501 abdominal and visceral FM is correlated with the CVD risk, this study confirms that HIIT is an
502 effective and time-efficient modality to reduce such risk in this population. HIIT + RT did not
503 potentiate this effect, but improved body composition by increasing the percentage of FFM,
504 including muscle mass. HIIT-induced greater total and (intra)-abdominal FM loss is not related
505 to changes in metabolic flexibility at rest, during moderate intensity exercise, or during the
506 recovery period. Additional studies are needed to better understand the underlying mechanisms

507 of HIIT-induced FM loss and to determine whether the concomitant muscle mass gain induced
508 by RT potentiates these adaptations.

509

510 **Acknowledgements**

511 The authors want to thank all the study participants for their kind collaboration, the nurse, Anne
512 Misson and Cyril Chomarar and Renaud Laurent for their kind assistance during the training
513 sessions and their help in data collection.

514

515 **Conflict of interest**

516 The results of this study are presented clearly, honestly, and without fabrication, falsification,
517 or inappropriate data manipulation. The results of the present study do not constitute
518 endorsement by the American College of Sports Medicine.

519

520 **Competing interests**

521 The authors declare that they have no competing interests.

522

523 **Authors' contributions**

524 MD was the PhD student on the MATISSE study and designed and supervised the different
525 training modalities. She met all participants, collected and analyzed all heart rate monitoring
526 data during training, supervised training sessions, collected and analyzed the data obtained for
527 RMR and during the prolonged exercise (FAT oxidation measurements), carried out the
528 anthropometric measurements and wrote the first and subsequent drafts of the paper. MR was
529 a co-investigator, and assisted with the study design. CM, PB and MD, physicians, assisted
530 with the study design, and oversaw the medical aspects of the study. AB and FM were sport
531 instructors, supervised training sessions with MD, and helped collecting data for RMR and

532 during the prolonged exercise (FAT oxidation measurements). NB conceived the study idea,
533 was responsible for the overall study design, and for monitoring data collection. BP was
534 responsible for all statistical analyses. All authors read and approved the final manuscript.

535

536 **Funding**

537 The MATISSE Study was funded by the University of Clermont Auvergne (AME2P
538 laboratory). The funders had no role in the study design, the collection, analysis, and
539 interpretation of data, the writing of the manuscript, and the decision to submit the article for
540 publication.

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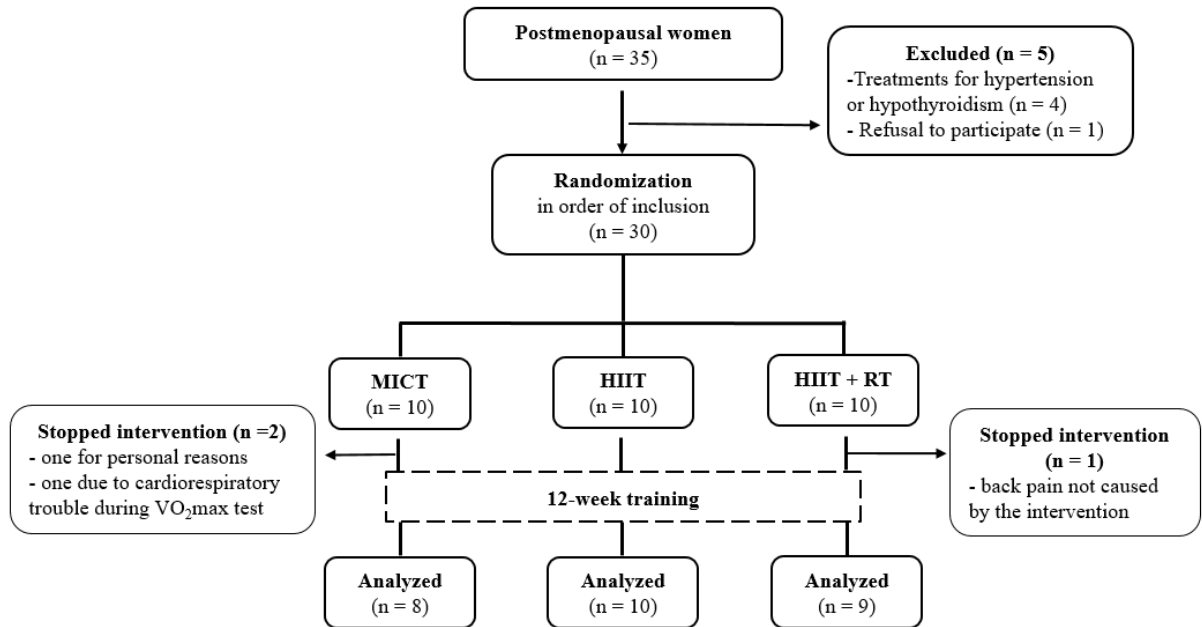
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676 **Figure Legends**

677 **Figure 1:** Flowchart of participants' recruitment.

678 HIIT: high-intensity interval training; MICT: moderate-intensity continuous training; HIIT +

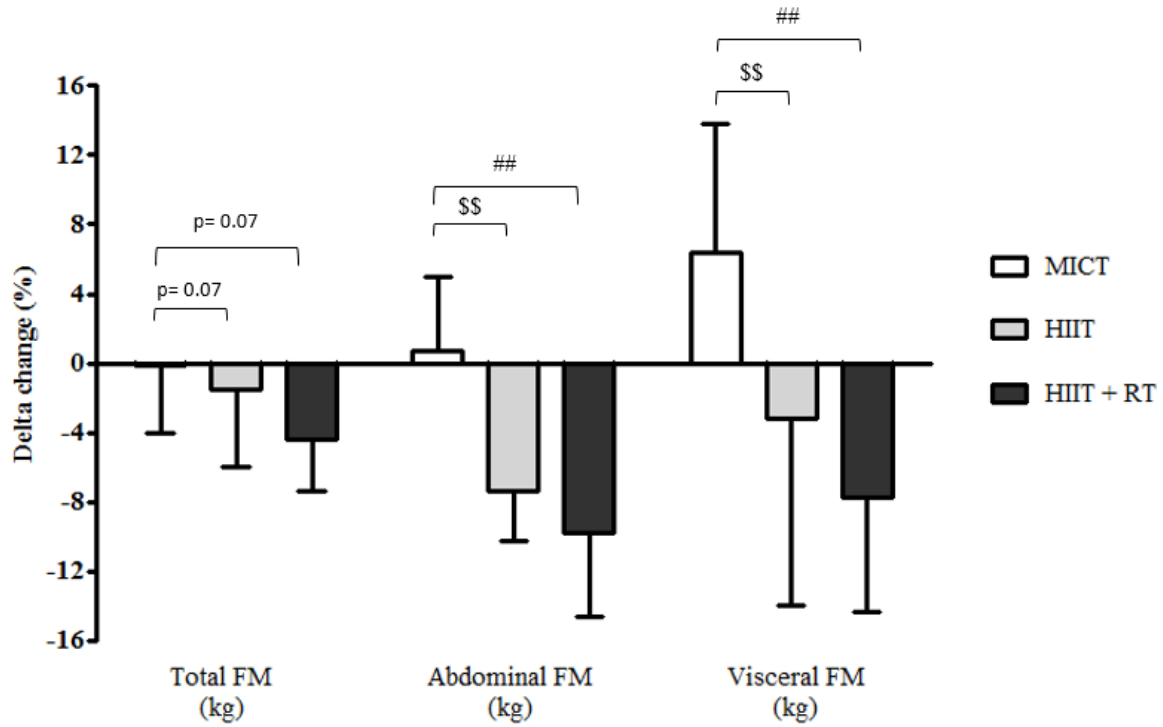
679 RT: high-intensity interval training + resistance training.



680

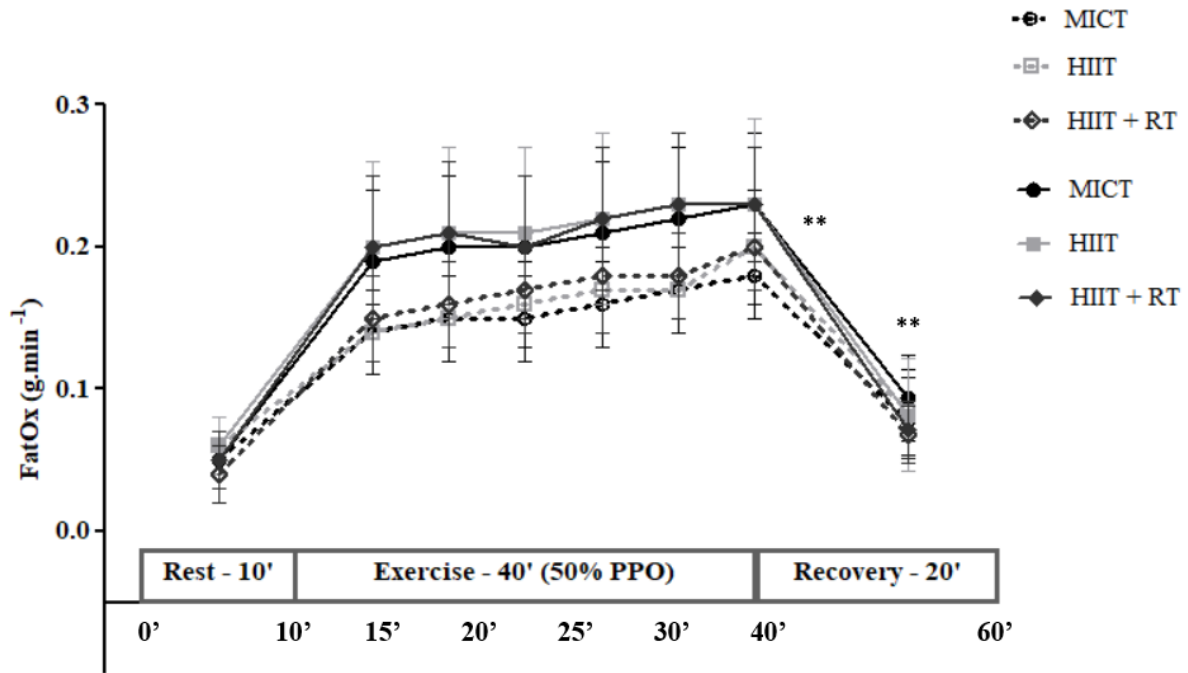
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682 **Figure 2:** Body composition changes (based on dual-energy X-ray absorptiometry imaging)
 683 between baseline and the end of the 12-week training program in the MICT (n = 8), HIIT (n =
 684 10) and HIIT + RT (n = 9) groups. Data are the mean \pm SD. MICT: moderate-intensity
 685 continuous training; HIIT: high-intensity interval training; HIIT + RT: high-intensity interval
 686 training + resistance training; FM: fat mass; delta change (%) = [(12 weeks – baseline/baseline)
 687 \times 100].
 688 #: $p \leq 0.01$: HIIT + RT vs. MICT group; \$: $p \leq 0.01$: HIIT vs. MICT group.



689
 690

691 **Figure 3:** Fat oxidation (FatOx, g.min⁻¹) at rest, during exercise (50% of PPO) and during the
 692 20min recovery in the MICT (n = 8), HIIT (n = 10) and HIIT + RT (n = 9) groups at baseline
 693 and after the 12-week intervention. Data are the mean ± SD. The values at rest correspond to
 694 the mean of the last 5 minutes. The values during the recovery period correspond to the mean
 695 of the 20min post-exercise period. Six values are presented for the cycling exercise period (at
 696 15, 20, 25, 30, 35 and 40min of exercise).
 697 ***: time effect (pre- vs post-intervention), p ≤0.005.
 698 MICT: moderate-intensity continuous training; HIIT: high-intensity interval training; HIIT +
 699 RT: high-intensity interval training + resistance training.



700

701

	MICT		HIIT		HIIT +RT		ANOVA (<i>p</i>)		
	Pre	Post	Pre	Post	Pre	Post	<i>G</i>	<i>T</i>	<i>G × T</i>
BMI (kg.m²)	31.2 ± 3.0	30.9 ± 2.8	31.5 ± 4.3	31.1 ± 4.4	31.4 ± 4.0	31.1 ± 3.7	0.99 0.00	0.02 0.21	0.98 0.00
Waist circumference (cm)	100.8 ± 5.4	99.2 ± 6.0	100.9 ± 9.3	97.1 ± 8.8	101.4 ± 10.0	98.8 ± 10.8	0.91 0.00	0.01 0.44	0.44 0.09
Hip circumference (cm)	109.7 ± 6.6	107.2 ± 7.3	110.1 ± 9.1	107.8 ± 7.6	106.3 ± 9.6	104.3 ± 8.1	0.58 0.04	0.001 0.44	0.97 0.09
Body weight (kg)	80.5 ± 7.1	79.7 ± 7.3	81.6 ± 12.7	80.8 ± 12.9	75.6 ± 8.9	74.9 ± 8.0	0.41 0.07	0.02 0.21	0.95 0.00
Total FM (kg)	30.7 ± 5.3	30.7 ± 5.4	27.7 ± 10.7	27.1 ± 10.6	28.1 ± 1.9	26.8 ± 1.8	0.50 0.06	0.002 0.34	0.06 0.21
Total FM (%)	37.9 ± 4.0	38.3 ± 4.4	33.7 ± 11.6	33.4 ± 11.5	36.9 ± 3.8	35.5 ± 3.8**	0.66 0.03	0.02 0.20	0.03 0.25
Total FFM (kg)	49.8 ± 3.7	49.1 ± 4.0	45.1 ± 15.6	44.9 ± 15.5	47.6 ± 4.2	48.1 ± 3.6	0.41 0.07	0.88 0.00	0.19 0.13
Total FFM (%)	62.1 ± 4.0	61.7 ± 4.4	56.3 ± 19.3	56.7 ± 19.3	64.1 ± 3.8	64.5 ± 3.9**	0.67 0.03	0.02 0.20	0.03 0.25
Muscle mass (kg)	47.7 ± 3.6	47.1 ± 3.9	43.3 ± 14.9	43.1 ± 14.9	45.7 ± 4.0	46.1 ± 3.3	0.44 0.07	0.79 0.00	0.29 0.10

Muscle mass (%)	59.5 ± 3.9	59.2 ± 4.2	54.0 ± 18.5	54.3 ± 18.6	60.7 ± 3.8	62.0 ± 3.9**	0.61 0.04	0.02 0.19	0.03 0.25
Total abdominal FM (kg)	7.6 ± 1.7	7.6 ± 1.7	7.4 ± 1.9	6.9 ± 1.9**	7.2 ± 1.7	6.5 ± 1.7**	0.67 0.03	≤ 10 ⁻⁸ 0.73	≤ 10 ⁻⁴ 0.48
Visceral FM (kg)	4.2 ± 1.7	4.4 ± 1.8	4.5 ± 1.1	4.3 ± 1.0	3.1 ± 1.4	2.9 ± 1.4#£	0.08 0.19	0.48 0.02	0.02 0.27
VO₂max (mL.min⁻¹.kg⁻¹)	25.3 ± 2.8	28.5 ± 2.9	30.5 ± 6.9	35.6 ± 6.4	31.5 ± 4.1	35.0 ± 4.1	0.04 0.24	≤ 10 ⁻⁷ 0.71	0.25 0.11
PPO (Watts)	85 ± 9	102 ± 12	96 ± 23	122 ± 21	104 ± 13	120 ± 14	0.04 0.24	≤ 10 ⁻⁷ 0.71	0.34 0.09
PPO (Watts.kg⁻¹)	1.1 ± 0.1	1.3 ± 0.2	1.2 ± 0.4	1.4 ± 0.7	1.4 ± 0.2	1.6 ± 0.2	0.1 0.18	≤ 10 ⁻⁷ 0.76	0.30 0.10

702

703 **Table 1: Anthropometric measurements, body composition and aerobic fitness in the MICT, HIIT and HIIT + RT groups at baseline**
704 **(pre) and at the end (post) of the training programs.**

705 Values are the mean ± SD.

706 G: group effect; T: time effect; G×T: group × time interaction.

707 BMI: body mass index; FM: fat mass; FFM: free-fat mass; Muscle mass = FFM – Bone Mineral Content from DXA; PPO: peak power output.

708 **: p ≤ 0.005 (pre vs. post in the same group); #: p ≤ 0.05 (HIIT + RT vs. MICT); £: p ≤ 0.05 (HIIT + RT vs. HIIT).

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	MICT		HIIT		HIIT +RT		ANOVA (<i>p</i>)		
	Pre	Post	Pre	Post	Pre	Post	<i>G</i>	η^2 <i>T</i>	<i>G</i> × <i>T</i>
REST									
RMR (kcal.day ⁻¹)	1403 ± 259	1430 ± 259	1615 ± 206	1514 ± 230	1426 ± 317	1392 ± 317	0.23 0.11	0.56 0.01	0.68 0.03
FatOx (g.min ⁻¹)	0.05 ± 0.02	0.05 ± 0.02	0.06 ± 0.02	0.06 ± 0.02	0.04 ± 0.02	0.05 ± 0.01	0.23 0.12	0.47 0.02	0.98 0.00
FatOx (%)	48.5 ± 17.5	50.3 ± 15.0	48.0 ± 14.5	53.7 ± 12.8	44.2 ± 15.5	48.8 ± 8.5	0.67 0.03	0.26 0.05	0.90 0.00
CHOOx (g.min ⁻¹)	0.14 ± 0.04	0.14 ± 0.03	0.16 ± 0.05	0.13 ± 0.04	0.16 ± 0.06	0.14 ± 0.05	0.73 0.02	0.16 0.08	0.95 0.05
CHOOx (%)	51.5 ± 17.5	49.7 ± 15.0	52.0 ± 14.5	46.3 ± 12.8	55.9 ± 15.5	51.3 ± 8.5	0.67 0.03	0.26 0.05	0.90 0.00
EE (kcal.min ⁻¹)	0.97 ± 0.18	0.99 ± 0.17	1.12 ± 0.14	1.05 ± 0.16	0.99 ± 0.22	0.97 ± 0.22	0.23 0.11	0.56 0.01	0.69 0.03
EXERCISE									
FatOx (g.min ⁻¹)	0.17 ± 0.03	0.21 ± 0.05	0.16 ± 0.03	0.22 ± 0.06	0.18 ± 0.03	0.22 ± 0.05	0.68 0.03	≤ 10⁻⁵ 0.48	0.81 0.02
FatOx (%)	41.9 ± 5.7	51.8 ± 10.8	39.8 ± 5.5	50.7 ± 11.1	40.6 ± 5.2	53.6 ± 10.9	0.72 0.03	≤ 10⁻⁴ 0.44	0.89 0.01
CHOOx (g.min ⁻¹)	0.60 ± 0.7	0.52 ± 0.12	0.67 ± 0.18	0.57 ± 0.15	0.72 ± 0.18	0.52 ± 0.17	0.46	0.006	0.46

							0.06	0.27	0.06
CHOOx (%)	58.1 ± 5.7	48.2 ± 10.8	60.2 ± 5.5	49.3 ± 11.1	59.4 ± 5.2	46.3 ± 10.9	0.72 0.03	≤ 10⁻⁴ 0.44	0.89 0.01
EE (kcal.min⁻¹)	3.7 ± 0.3	3.9 ± 0.4	4.0 ± 0.8	4.0 ± 0.7	4.3 ± 0.9	4.0 ± 0.6	0.45 0.06	0.63 0.00	0.29 0.10
RECOVERY									
FatOx (g.min⁻¹)	0.08 ± 0.03	0.09 ± 0.03	0.08 ± 0.03	0.08 ± 0.04	0.07 ± 0.02	0.07 ± 0.02	0.69 0.03	≤ 10⁻⁵ 0.48	0.81 0.02
FatOx (%)	52.5 ± 10.8	57.2 ± 12.1	52.6 ± 10.8	55.9 ± 11.0	47.6 ± 12.3	53.9 ± 10.0	0.72 0.03	≤ 10⁻⁴ 0.44	0.89 0.01
CHOOx (g.min⁻¹)	0.20 ± 0.05	0.21 ± 0.10	0.18 ± 0.04	0.18 ± 0.09	0.21 ± 0.06	0.17 ± 0.06	0.47 0.06	0.006 0.27	0.45 0.06
CHOOx (%)	47.5 ± 10.8	42.8 ± 12.1	47.4 ± 10.8	44.1 ± 11.0	52.4 ± 12.3	46.0 ± 10.0	0.72 0.03	≤ 10⁻⁴ 0.44	0.89 0.01
EE (kcal.min⁻¹)	1.5 ± 0.3	1.6 ± 0.4	1.4 ± 0.3	1.4 ± 0.6	1.4 ± 0.3	1.3 ± 0.3	0.45 0.06	0.63 0.01	0.29 0.10

712

713 **Table 2: Substrate utilization and energy expenditure at rest, during moderate intensity continuous exercise (50% of PPO) and during**
714 **the 20min recovery time in the MICT, HIIT, and HIIT + RT groups at baseline (pre) and after (post) the training programs.**

715 Values are the mean ± SD.

716 G: group effect; T: time effect; G×T: group × time interaction.

717 RMR: resting metabolic rate; EE: energy expenditure; FatOx: fat oxidation; CHOOx: carbohydrate oxidation.

	MICT		HIIT		HIIT + RT		ANOVA (<i>p</i>)		
	Pre	Post	Pre	Post	Pre	Post	<i>G</i>	η^2 <i>T</i>	<i>G</i> × <i>T</i>
Glycemia (mmol.L ⁻¹)	1.2 ± 0.7	1.2 ± 0.4	1.2 ± 0.3	1.2 ± 0.3	1.2 ± 0.6	1.2 ± 0.7	0.19 0.13	0.47 0.02	0.74 0.03
Insulinemia (μU.L ⁻¹)	11.2 ± 3.	9.1 ± 3.3	12.9 ± 14.8	12.5 ± 13.0	11.5 ± 3.3	11.7 ± 4.4	0.82 0.02	0.27 0.05	0.79 0.03
HbA1c (%)	5.6 ± 0.5	5.5 ± 0.4	6.1 ± 0.9	6.0 ± 0.7	5.8 ± 0.2	5.7 ± 0.2	0.19 0.13	0.52 0.02	0.50 0.06
HOMA-IR	3.0 ± 1.2	2.2 ± 0.8	3.9 ± 4.7	3.8 ± 4.4	2.8 ± 0.8	3.0 ± 1.4	0.64 0.04	0.39 0.03	0.42 0.07
Total Cholesterol (mmol.L ⁻¹)	6.3 ± 1.3	6.3 ± 1.3	5.6 ± 1.1	5.4 ± 1.2	6.2 ± 1.0	6.2 ± 1.0	0.27 0.10	0.43 0.03	0.86 0.01
HDL-C (mmol.L ⁻¹)	1.7 ± 0.4	1.6 ± 0.1	1.7 ± 0.9	1.7 ± 0.5	1.7 ± 0.5	1.7 ± 0.4	0.82 0.01	0.77 0.00	0.69 0.03
LDL-C (mmol.L ⁻¹)	3.5 ± 1.6	3.6 ± 1.4	3.3 ± 0.8	3.4 ± 0.8	3.9 ± 1.0	3.9 ± 0.8	0.40 0.08	0.83 0.00	0.79 0.02
TG (mmol.L ⁻¹)	1.4 ± 1.1	1.1 ± 0.5	1.2 ± 0.7	0.9 ± 0.4	1.2 ± 0.5	1.2 ± 0.6	0.43 0.07	0.02 0.22	0.41 0.07

720 **Table 3: Glycemic control and lipid profile in the MICT, HIIT and HIIT + RT groups at baseline (pre) and after (post) the training**
721 **programs.**

722 Values are the mean \pm SD.

723 G: group effect; T: time effect; G \times T: group \times time interaction.

724 HDL: High Density Lipoproteins, LDL: Low Density Lipoproteins, C, cholesterol; TG: Triglycerides.

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