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Title: Effect of moderate vs. vigorous exercise intensity on body composition in young untrained adults: The ACTIBATE randomized controlled trial

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Running Head: Moderate vs. vigorous exercise intensities for body composition

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ABSTRACT

The present study aimed to investigate the effect of a 24-weeks aerobic + resistance training programs at moderate vs. vigorous intensity on body composition, and the persistence of the changes after a 10-month free living period, in young untrained adults. This report is based on a secondary analysis from the ACTIBATE single-center unblinded randomized controlled trial. A total of 144 young adults (65.6% women) aged 18-25 years were randomly allocated to 3 different groups: (i) aerobic + resistance exercise training program based on the international physical activity recommendations at vigorous intensity (Ex-vigorous group), (ii) at moderate intensity (Ex-moderate group), and (iii) control group (no exercise). Body composition outcomes were determined by a DXA scanner. Both Ex-Vigorous and Ex-Moderate decreased body weight, fat mass and visceral adipose tissue mass in a similar manner (all $P < 0.04$). After a 10 months free living period, these parameters returned to baseline levels in both exercise groups (all $P < 0.03$). No differences between the exercise groups and the control group were noted in lean mass changes (all $P > 0.1$). A 24-week aerobic + resistance training intervention based on the international physical activity recommendations were enough to improve body weight, fat mass and visceral adipose tissue mass in untrained young adults, independently of the exercise intensity (moderate vs. vigorous).

1 INTRODUCTION

2 The prevalence of overweight and obesity has dramatically increased in most countries over
3 the last decades, reaching pandemic proportions (Elagizi et al., 2018; Skinner et al., 2015).
4 Previous studies have reported a higher prevalence of hypertension, coronary heart disease, or
5 hearth failure in obese individuals when compared with their lean counterparts, making
6 obesity the second cause of all-cause mortality, after tobacco consumption (Elagizi et al.,
7 2018; Ng et al., 2014). Obesity is defined as a excessive amount of adipose tissue
8 accumulated in the whole body that result in serious problems for human' health (Elagizi et
9 al., 2018). Recent investigations have demonstrated that obesity is a heterogeneous condition
10 whose consequences depend on the regional distribution of adipose tissue (Ladeiras-Lopes et
11 al., 2017; Wajchenberg, 2000). Concretely, an excess of visceral adipose tissue (VAT) has
12 been better correlated with increased risk of cardiovascular disease and premature death than
13 the whole-body FM (Ladeiras-Lopes et al., 2017; Wajchenberg, 2000).

14 Sedentary lifestyles and low physical activity levels increase obesity incidence and decrease
15 lean mass (LM) in healthy individuals and patients (Polyzos & Margioris, 2018). Taking
16 these facts into account, numerous studies have been conducted to determine the best type of
17 exercise training capable of improving body composition, i.e., decreasing FM while
18 preserving or incrementing LM (Petridou et al., 2018; Westerterp, 2018).

19 Aerobic training reduces whole body and visceral adiposity (McTiernan et al., 2007), and
20 increases fat oxidation rates in skeletal muscle and liver (Jeukendrup et al., 1998), improves
21 muscle mitochondrial activity (Häkkinen et al., 2003), and reduces levels of proinflammatory
22 cytokines (Cronin et al., 2017). On the other hand, other studies revealed that resistance
23 training, in addition to increasing LM, is also able to enhance the carbohydrate oxidation in
24 skeletal muscle and muscle anabolism (Silva et al., 2014), elevating resting metabolic rate

25 (Silva et al., 2014) and, consequently, increasing energy expenditure (Elagizi et al., 2018;
26 Lavie et al., 2016). Therefore, it has been suggested that aerobic + resistance training could
27 be an excellent option to improve body composition (Davitt et al., 2014; Donges et al., 2013;
28 Michell et al., 2014). Indeed, previous studies have demonstrated that resistance training not
29 only improves muscle mass and strength (Carbone et al., 2020; Kaminsky et al., 2022), but
30 also reduces the risk of cardiovascular disease and all-cause mortality (Liu T et al., 2019)

31 Current physical activity recommendations provided by the World Health Organization
32 (WHO) (Bull et al., 2020) and by the US Department of Health and Human Services (Piercy
33 et al., 2018), includes an aerobic + resistance training methodology. They propose 150-300
34 minutes of moderate intensity or 75-150 minutes of vigorous intensity aerobic exercise
35 combined with muscle-strengthening activities at moderate or greater intensity on 2 or more
36 days a week. These recommendations are based on evidence showing that this exercise dose
37 is an effective tool for reducing all-cause mortality and cardiometabolic disease incidence,
38 also achieving a healthier body weight and composition (Bull et al., 2020; Piercy et al.,
39 2018). Several studies have reported a significant improvement of body composition after the
40 application of an aerobic + resistance training program in sedentary men (Ghahramanloo et
41 al., 2009; Michell et al., 2014; Shaw et al., 2010) and women (Davitt et al., 2014). However,
42 to avoid the prevalence of lifestyle-related diseases, it is important not only to perform an
43 exercise training program, but also to maintain the adherence to an active lifestyle, since
44 physiological improvements produced by exercise could be lost following a detraining period
45 (Davitt et al., 2014).

46 Following the WHO physical activity guidelines, the relationship of physical activity and
47 adiposity in adult aged 18 to 64 years is still unclear since (Bull et al., 2020). In general
48 terms, it has been demonstrated that higher levels of physical activity reduce levels of
49 adiposity and prevent weight gain (Bull et al., 2020). However, the WHO guidelines indicates

50 that further research is needed to establish consistent results and effects (Bull et al., 2020). To
51 our knowledge, there are no studies comparing the effects of a moderate vs. vigorous
52 intensity long-term aerobic + resistance training program (matching training time) based on
53 the international physical activity recommendations proposed by the WHO (Bull et al., 2020)
54 on body composition in young untrained adults. Moreover, little is also known about the
55 effects of long-term detraining after an aerobic + resistance training program in untrained
56 young adults of both sexes. Therefore, this work aimed to investigate the effect of a 24-weeks
57 aerobic + resistance training programs at moderate vs. vigorous intensity on body
58 composition in young untrained adults. A secondary aim of the study was to investigate
59 changes in body composition after 10-months of free living after the training program.

60 **METHODS**

61 **Experimental design**

62 The present study includes a secondary analysis from the single-center ACTIBATE
63 randomized controlled trial (Sanchez-Delgado, G, Martinez-Tellez, B, Olza, J, Aguilera, CM,
64 Labayen, I., Ortega, FB, Ruiz, 2015), a 24-week exercise intervention conducted according to
65 the Consolidated Standards of Reporting Trials (CONSORT) guidelines (Schulz et al., 2010;
66 Welch et al., 2017) (see Supplementary Table S1). The participants were evaluated at the
67 baseline, after 12-weeks of the intervention, at the end of the 24-weeks of the intervention,
68 and 10 months after the end of the training program (follow-up). The participants were
69 randomly assigned to either an aerobic + resistance training program based on the
70 international physical activity recommendations at moderate intensity (Ex-Moderate group),
71 or at vigorous intensity (Ex-Vigorous group), or a control group (no exercise training). The
72 randomization process was conducted after the baseline assessment.

73 **Participants**

74 A total of 144 young adults (65.6% women) were enrolled in this randomized control trial
75 (the ACTIBATE study; ClinicalTrials.gov ID: NCT02365129) (Sanchez-Delgado, G,
76 Martinez-Tellez, B, Olza, J, Aguilera, CM, Labayen, I, Ortega, FB, Ruiz, 2015), which was
77 conducted at the Instituto Mixto Universitario Deporte y Salud (iMUDS) at the University of
78 Granada (Spain). It was performed according to the last revision of the Declaration of
79 Helsinki, and was approved by the Human Research Ethics Committee of both University of
80 Granada (n° 924) and Servicio Andaluz de Salud (Centro de Granada, CEI-Granada) [0838-
81 N-2017]. The participants were recruited through social networks, local media and posters
82 allocated at the Faculties of the University of Granada. The participants contacted the
83 research team by e-mail, Facebook or Twitter and several appointments were made in order
84 to carry out a detailed explanation of the study objectives, assessments to be undertaken,
85 inclusion criteria, and the exercise intervention. The inclusion criteria were as follows: (i)
86 being between 18 and 25 years old, (ii) having a body mass index (BMI) between 18.5 and 35
87 kg/m², (iii) not engaging in a regular physical activity programme (>20 min on >3
88 days/week), (iv) having a stable body weight during the last 3 months (changes <3kg), (iv)
89 being considered suitable for exercise intervention after a medical examination, (v) not taking
90 medication for chronic diseases, (vi) not consuming tobacco, and (vii) signing a written
91 informed consent form.

92 **Interventions**

93 The exercise training program designed for this study has been explained in detail elsewhere
94 (Sanchez-Delgado, G, Martinez-Tellez, B, Olza, J, Aguilera, CM, Labayen, I, Ortega, FB,
95 Ruiz, 2015). Briefly, both Ex-Moderate and Ex-Vigorous group performed an aerobic +
96 resistance training based on the minimum international physical activity recommendations
97 (Bull et al., 2020). Importantly, both interventions were time-matched with manipulation of the
98 intensity and, therefore also the caloric dose (i.e., the Ex-Vigorous group trained at higher

99 intensity and had a higher exercise energy expenditure). For both groups, aerobic training time
100 was 150 min/week, and the resistance training time was ~80 min/week. For the aerobic training,
101 the Ex-Vigorous group completed 75 min/week at 60% of heart rate reserve (moderate
102 intensity) and 75 min/week at 80% of heart rate reserve (vigorous intensity), while the Ex-
103 Moderate group performed the total of 150 min/week of aerobic training at 60% of heart rate
104 reserve. The resistance training was performed at 50% of one repetition maximum for the Ex-
105 Moderate group, and at 70% of one repetition maximum for the Ex-Vigorous group. Different
106 ergometers were used to do the aerobic training (i.e., treadmill, cycle ergometer, and elliptical
107 ergometer), and weight bearing and guided pneumatic machines were used to perform strength
108 exercises that involved upper and lower body muscle groups for the resistance training (i.e.,
109 bench press, lateral pull down, squat, dead lift and hip thrust among others). Compensatory
110 exercises were also prescribed (i.e., flexibility and core stability exercises among others) in
111 order to reduce the injury risk and to increase the participant's adherence. The training
112 frequency was 3-4 sessions/week at the participant's choice. We adjusted the length of the
113 training sessions to ensure that all participants had the same weekly dose. Resistance training
114 was performed 2 out of these 3 or 4 sessions/week, thus 1 or 2 sessions/week consisted solely
115 on aerobic training. A standardized warm-up was performed at the beginning of each training
116 session, and an active global stretching protocol was conducted as a cooling-down phase. The
117 heart rate was continuously monitored. All sessions were performed in reduced groups and
118 were supervised by certified trainers. We systematically registered the daily attendance at the
119 sessions, and the participants were contacted upon any missing session. The participants were
120 asked to replace these sessions on alternative days, or were invited to train on their own when
121 attending was not possible.

122 The participants randomly assigned to the control group received verbal information about
123 healthy habits including the international physical activity recommendations (Bull et al., 2020),

124 and also nutritional advices based on the Mediterranean diet patterns (Estruch & Bach-Faig,
125 2018).

126 **Measurements**

127 Body weight and height were assessed using an electronic scale and analogue stadiometer
128 (SECA, model 799, Electronic Column Scale, Hamburg, Germany), with a precision of 0.1 kg
129 and 0.1 cm, respectively. The participants were evaluated barefoot with light clothes and
130 standing at the base of the stadiometer, positioning their head in the Frankfort plane. After that,
131 the BMI was calculated as $\text{body weight(kg)/body height(m)}^2$. Body composition outcomes (i.e.,
132 FM and FM percentage, VAT, LM [total, legs and arms LM], bone mineral content [BMC] and
133 bone mineral density [BMD]) were determined by a whole-body dual-energy X-ray
134 absorptiometry scanner (Hologic Wi, Hologic Inc., Bedford, MA, USA). VAT was estimated
135 for a region of interest extended from the midpoint of the intervertebral space between the T12
136 and L1 vertebrae to the midpoint of the intervertebral space between the L4 and L5 vertebrae.
137 All DXA assessments followed the manufacturer's recommendations.

138 **Statistical Analysis**

139 Since the current study is based on a secondary analysis from the ACTIBATE randomized
140 controlled trial (which aimed to investigate the effects of a 24-week supervised exercise
141 intervention on brown adipose tissue volume and activity), no power calculation was performed
142 regarding the present outcomes.

143 Descriptive parameters are expressed as mean \pm standard deviation unless otherwise stated. We
144 checked the normality of our data by the Shapiro-Wilk test, visual check of histograms, and Q-
145 Q plots. We analysed the Sex \times Time interaction effects on body composition outcomes by a
146 mixed model including Sex and Time as fixed effects. Given that there was no Sex interaction
147 in any case (all $P > 0.1$), all statistical analyses were conducted for men and women together.

148 The analyses were conducted following a per protocol approach and, therefore, no imputation
149 methods were applied. We calculated different differences for each outcome as: (i) week 12 -
150 value minus baseline value, (ii) week 24 value minus baseline value, and (iii) 10 months after
151 the program value minus baseline value. To examine the influence of the intervention on body
152 weight and composition outcomes (dependent variable in all time-points [i.e., changes after 12-
153 weeks of the intervention, changes after 24-weeks of the intervention, and changes after a 10
154 months free living period]), analyses of covariance (ANCOVA) were conducted adjusting for
155 the baseline values (model 1). Bonferroni post hoc test for correcting for multiple comparisons
156 were also performed. Additional models were built controlling for baseline values and sex
157 (model 2), and for baseline values and age (model 3). We additionally performed as sensitive
158 analysis: (i) mixed-effects regression models with random intercepts to the primary outcomes
159 (i.e., body weight, FM, FM percentage, VAT mass, LM (total, legs and arms LM), BMC and
160 BMD) and (ii) analyses excluding those participants that did not reach a minimum of 70% of
161 attendance and a minimum of 40% of adherence to the pre-determined intensity fixed for each
162 exercise group. Pearson's correlation analysis was used to correlate attendance to the exercise
163 training program and adherence to the pre-determined intensity pre-determined for each
164 exercise group with changes in anthropometric and body composition parameters.

165 We established a level of significance of $P < 0.05$. The Statistical Package for Social Sciences
166 (SPSS, v. 22.0, IBM SPSS Statistics, IBM Corporation, Chicago, IL, USA) was selected to
167 perform the statistical analysis. The GraphPad Prism 5 (GraphPad Software, San Diego, CA,
168 USA) was used for generate the graphical plots.

169 **RESULTS**

170 The flow-chart is presented in Figure 1. A total of 144 participants were randomly assigned to
171 either the control group (N=54), the Ex-Moderate group (N=48), or the Ex-Vigorous group

172 (N=44). A total of 36 participants (~78%) finished the intervention program in the Ex-
173 Moderate group, while 36 participants (~82%) finished the intervention program in the Ex-
174 Vigorous group, and 33 participants (~75%) finished the 24-week participation in the control
175 group. The attendance average at the exercise sessions was ~95% for the Ex-Moderate group,
176 and ~96% for the Ex-Vigorous group. We registered a loss to the 10-month follow-up of 30%
177 in the control group, 22% in the Ex-Moderate group, and 19% in the Ex-Vigorous group.

178 ***Figure 1***

179 Table 1 shows the baseline descriptive characteristics of the study participants together and
180 separated by groups.

181 ***Table 1***

182 **Effect of aerobic + resistance training on body weight and composition after 12-weeks of** 183 **intervention**

184 Participants of the Ex-Moderate and Ex-Vigorous significantly decreased their body weight,
185 FM, and FM percentage as compared with the control group (all $P < 0.042$; Figure 2A, 2C, and
186 2E), while no significant between-group differences were noted on changes in VAT mass and
187 LM (all $P > 0.09$; Figure 2G and 2I; Table 2). We did not observe differences in changes in body
188 weight and composition between the Ex-Moderate and Ex-Vigorous groups (all $P > 0.3$; Figure
189 2A, 2C, 2E, 2G and 2I; Table 2).

190 ***Table 2***

191 **Effect of aerobic + resistance training on body weight and composition after 24-weeks of** 192 **intervention**

193 Participants of the Ex-Moderate and Ex-Vigorous significantly decreased their body weight,
194 FM, FM percentage, and VAT mass as compared with the control group (all $P < 0.025$; Figure

195 2A, 2C, 2E, and 2G; Table 2), while no significant between-group differences were noted on
196 changes in LM ($P=0.104$; Figure 2I; Table 2). We did not observe differences on changes in
197 body weight and composition between the Ex-Moderate and Ex-Vigorous groups (all $P>0.6$;
198 Figure 2A, 2C, 2E, 2G and 2I; Table 2).

199 **Effect of aerobic + resistance training on body weight and composition 10 months after**
200 **completing the training program**

201 ANCOVA unveiled no significant differences between groups in body weight, FM, FM
202 percentage, VAT, and LM after 10 months follow-up compared with the baseline levels (all
203 $P\geq 0.5$, Figure 2; Table 2).

204 ***Figure 2***

205 **Effect of aerobic + resistance training on body weight and composition after 12-weeks,**
206 **24-weeks, and a 10 months free living period: sensitivity analyses**

207 All the above-mentioned findings persisted after conducting the mixed-effects regression
208 models analyses in all body weight and composition outcomes (Figure 2B, 2D, 2F, 2H, and 2J;
209 Table 2). Moreover, no significant changes in response to the exercise interventions were noted
210 neither in BMC or BMD compared to the control group (Supplementary Figure S1). All the
211 results remained in all cases when sex and age were included in the model as a covariate
212 (Supplementary Table S2).

213 Interestingly, 11 participants of the control group (~32%) reported having performed regular
214 exercise during the intervention study. Therefore, to compare both exercise training groups
215 (i.e., Ex-Moderate group and Ex-Vigorous group) with participants of the control group that
216 did not perform regular physical exercise during our intervention, we conducted an additional
217 analysis excluding those participants. Similar results were revealed in term of changes in body
218 weight, FM, FM percentage, and VAT mas after 12 weeks, after 24 weeks and 10 months

219 follow-up of the intervention study (data not shown). However, while no significant between-
220 group differences were noted on changes in LM after 12 weeks of the intervention (all $P > 0.09$;
221 Figure 3A), the participants of the Ex-Moderate and Ex-Vigorous significantly increased their
222 LM as compared with the control group ($P < 0.001$; Figure 3A). Nevertheless, these exercise-
223 related changes in LM were not maintained in both intervention groups 10 months after
224 completing the training program (all $P > 0.4$; Figure 3A). Importantly, these results did not
225 change neither after performing the mixed-effects regression models analyses (Figure 3B) or
226 after controlling the analyses by sex and age (data not shown).

227 ***Figure 3***

228 We found a lack of association between attendance to the exercise training program and the
229 pre-determined intensity fixed for each exercise group with changes in body weight, FM, FM
230 percentage, VAT, and LM after the intervention study (all $P \geq 0.05$).

231 **DISCUSSION**

232 The main findings of the present study were that 24 weeks of aerobic + resistance training
233 based on current WHO' physical activity guidelines improved body weight and composition
234 (i.e., FM, FM percentage and VAT mass) in young untrained adults - independently of the
235 predetermined exercise intensity (moderate vs. vigorous intensity; training time-matched) -,
236 while no significant between-group differences were noted on changes in LM. Importantly,
237 these improvements were already observed by the twelfth week of the training program. Thus,
238 no body weight and composition changes were produced during the last 3-months of the
239 exercise program (except for VAT mass that was only decreased after 24 weeks of aerobic +
240 resistance training, independently of the exercise intensity). However, the above-mentioned
241 positive changes did not persist 10 months after the completion of the training program.

242 Within the current study, we observed significant differences in FM and FM percentage

243 between the Ex-Moderate group (a FM decrease of ~7%) and the Ex-Vigorous group (a FM
244 decrease of ~9%) compared with the control group, with no differences between both exercise
245 groups. These findings concurred with those obtained by previous studies which applied
246 slightly different aerobic + resistance training programs in young sedentary men (a FM
247 decrease of ~20%) (Ghahramanloo et al., 2009; Shaw et al., 2010), in sedentary middle-aged
248 men (a FM decrease of ~5%) (Michell et al., 2014), and in active young women (a FM decrease
249 of ~5%) (Davis et al., 2008). However, Davitt et al. reported that an 8-weeks aerobic +
250 resistance training program did not produce significant improvements of FM in college
251 underclassmen women (Davitt et al., 2014). Although it is expected that an aerobic + resistance
252 training program induces significant decrements of FM (specially in untrained individuals)
253 (Ghahramanloo et al., 2009; Michell et al., 2014; Shaw et al., 2010), the results reported by
254 Davitt et al. (Davitt et al., 2014) may be explained because they conducted a short-duration
255 intervention program compared with other studies (Davis et al., 2008; Ghahramanloo et al.,
256 2009; Michell et al., 2014; Shaw et al., 2010). In addition, they also recognized that the
257 participants of their study were instructed to maintain their regular nutritional habits during the
258 intervention program, and it has been previously described that a FM gain is typically seen in
259 college underclassmen (Cluskey & Grobe, 2009; Gillen & Lefkowitz, 2011).

260 It is well-known the clinical relevance of VAT, since numerous studies have demonstrated a
261 strong association between VAT mass and greater risk of metabolic syndrome, heart failure,
262 hypertension and/or diabetes mellitus, even in the absence of obesity (determined by a BMI>30
263 kg/m²) (Okura et al., 2005; Shaw et al., 2010). Despite literature has reported that both
264 endurance and resistance training are able to reduce VAT mass (Keating et al., 2015; Strasser
265 et al., 2012), data are scarce regarding the effects of an aerobic + resistance supervised training
266 program on VAT. Shaw et al. observed a significant decrement of abdominal adipose tissue
267 estimated by waist circumference (a decrease of ~3%) after 8-weeks of aerobic + resistance

268 training in sedentary young men (Shaw et al., 2010). However, it remains unknown whether a
269 longer aerobic + resistance training program applying different exercise intensities reduces
270 VAT mass in both untrained young men and women. In the current study, we showed, for the
271 first time, that a 24-weeks aerobic + resistance training program based on the international
272 physical activity recommendations (Bull et al., 2020) significantly reduced VAT mass,
273 estimated by DXA, in young untrained adults, independently of the exercise intensity applied
274 (a decrease of ~15% in both Ex-Moderate and Ex-Vigorous groups). Moreover, we also
275 observed that 12 weeks of aerobic + resistance training seems not to be time enough to induce
276 VAT mass reductions in untrained healthy adults of both sexes.

277 The results of this study suggested that there were no significant differences in LM between
278 both the Ex-Moderate and the Ex-Vigorous groups compared with the control group. These
279 unexpected findings did not concur with those reported by previous investigations which
280 observed that an concurrent training program improved LM in sedentary young men (a LM
281 increase of ~2%) (Ghahramanloo et al., 2009), in sedentary middle-aged men (a LM increase
282 of ~1%) (Michell et al., 2014), in sedentary young women (a LM increase of ~2%) (Davitt et
283 al., 2014), and in active young women (a LM increase of ~3%) (Davis et al., 2008). An
284 important point to note is that the participants of our study allocated in the control group
285 received verbal information about healthy habits including the international physical activity
286 recommendations provided by the WHO (Bull et al., 2020), and also nutritional advices based
287 on the traditional Mediterranean diet patterns (Estruch & Bach-Faig, 2018). In this context, 11
288 participants of the control group reported having performed regular physical exercise and/or
289 modified their nutritional habits during the intervention study. Considering that young
290 individuals are characterized by an increased muscle anabolic signalling and myofibrillar
291 protein synthesis (Harber et al., 2012; Kumar et al., 2009), it is plausible that the lack of
292 differences in LM changes between the experimental groups and the control group could be

293 explained by the inclusion of participants that performed regular physical activity and/or
294 modified their dietary habits in the control group. To test this hypothesis, we conducted the
295 same analysis excluding these participants, and we found significant differences in LM
296 between both Ex-Moderate and Ex-Vigorous groups compared with the control group after a
297 24-weeks aerobic + resistance training program (an increase of ~5% in both cases), while only
298 the Ex-Vigorous group showed a significant improvement in LM compared with the control
299 group after 12-weeks of the intervention program (an increase of ~4%). These results suggest
300 that the training program induced a 2-fold higher increase in LM as compared with those
301 reported by previous investigations (Davis et al., 2008; Davitt et al., 2014; Ghahramanloo et
302 al., 2009; Shaw et al., 2010), which could be explained by a longer duration (24-weeks vs. <16-
303 weeks), a higher total training volume (150 minutes/weeks vs. <120 minutes/week of aerobic
304 training), and the supervised and structured nature of the intervention program. Moreover, the
305 high importance of the aerobic training part in our intervention could also explain the obtained
306 results.

307 Taking into account the findings obtained in our study, we suggest that a 12 to 24-weeks
308 aerobic + resistance training program is an effective strategy to improve body composition in
309 young untrained adults. However, to avoid the prevalence of chronic diseases related to body
310 weight gain and/or body composition changes, it is important to create adherence to an active
311 lifestyle, since exercise-induced adaptations could be lost following a detraining period (Davitt
312 et al., 2014). Rossi et al. observed significant improvements in FM and LM after the application
313 of a 16-weeks aerobic + resistance training program in sedentary postmenopausal women, that
314 returned to pre-training values after 6 months (Rossi et al., 2017). These findings concur with
315 those obtained in our study, since the enhancements observed in FM, LM, and VAT mass after
316 the intervention program in both Ex-Moderate and Ex-Vigorous groups, disappeared 10
317 months after completing the intervention. Therefore, future studies are needed to investigate

318 the application of different strategies that promote regular physical activity habits after a
319 aerobic + resistance training intervention. Curiously, we observed a slightly lower dropouts'
320 rates in the Ex-Vigorous group compared with the Ex-Moderate (82% vs. 78%, respectively).
321 Thus, the organization of informative talks after an exercise intervention giving information
322 about the importance of performing regular physical activity at vigorous intensity (Bull et al.,
323 2020) (“WHO | Global Recommendations on Physical Activity for Health,” 2015) and also
324 nutritional advices based on the traditional Mediterranean diet patterns (Estruch & Bach-Faig,
325 2018), caloric restriction(He et al., 2021), or time-restricted eating (Zhang et al., 2022) might
326 be a correct approach to maintain and/or improve the body composition changes obtained
327 during an aerobic + resistance training intervention (Donnelly et al., 2009).

328 The limitations of this study need to be considered when interpreting the findings. The high
329 number of participants allocated in the control group that performed regular physical activity
330 exercise and or modified their nutrition habits during our intervention program make the
331 comparison between groups difficult to interpret. The follow-up time may have been
332 insufficient to well-understand the evolution of body composition changes in response to a
333 free-living period, thus future studies should include different follow-up measurements (i.e., 3-
334 months follow-up, 6-months follow-up, 9-months follow-up, and 12-months follow-up). DXA
335 only provides an estimation of VAT and, therefore, the use of a gold standard method (i.e.,
336 magnetic resonance imaging) for this purpose would be desirable in future studies. Finally, we
337 only recruited untrained young adults aged between 18 to 25 years, thus we cannot extend these
338 results to younger, older, or trained individuals.

339 In summary, the findings of the current study pointed out that 24 weeks of aerobic + resistance
340 training at moderate intensity based on the international physical activity recommendations
341 provided by the WHO improve body weight and composition in a similar way as vigorous
342 intensity in untrained young adults, while no significant between-group differences were noted

343 on changes in LM. However, the effects were reverted 10-month after completing the training
344 program.

345 Considering that the present update of the WHO international physical activity guidelines
346 based on the scientific evidence (Bull et al., 2020) - which suggest an increment of the aerobic
347 exercise volume until 300 min/week at moderate intensity or 150 min/week at vigorous
348 intensity (Piercy et al., 2018) - future studies are needed to elucidate whether a aerobic +
349 resistance training program with higher volume is able to induce extra benefits on body
350 composition in other people with similar and different biological characteristics than our study'
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352

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376

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Table 1. Baseline descriptive characteristics of the study participants.

	N	All	N	Control	N	Ex-Moderate	N	Ex-Vigorous
Age (years)	98	22.1±2.2	34	22.2±2.1	32	22.0±2.1	32	22.1±2.3
Sex [n, (%)]	98		34		32		32	
Men		30 (30.6)		13 (38.2)		9 (28.1)		8 (25.0)
Women		68 (69.4)		21 (61.8)		23 (71.9)		24 (75.0)
Body weight (kg)	98	69.6±14.6	34	68.6±16.2	32	69.4±12.8	32	70.8±15.0
Body height (cm)	98	167.3±8.0	34	167.1±8.1	32	166.7±8.6	32	168.0±7.6
Body mass index (kg/m ²)	98	24.8±4.3	34	24.4±4.5	32	24.9±3.9	32	25.0±4.4
Fat mass (kg)	98	24.6±8.1	34	23.1±7.7	32	25.2±8.3	32	25.5±8.2
Fat mass (%)	98	35.8±7.5	34	34.4±7.3	32	36.7±8.3	32	36.5±6.9
Visceral adipose tissue (g)	98	341±172	34	322±173	32	358±164	32	346±183
Lean mass (kg)	98	41.1±9.1	34	41.7±10.7	32	40.4±8.0	32	41.2±8.5
Lean mass (%)	98	58.9±9.2	34	60.8±7.1	32	58.6±7.9	32	58.8±5.9
Legs lean mass (kg)	98	13.2±3.7	34	13.6±4.1	32	13.1±2.9	32	13.4±3.7
Arms lean mass (kg)	98	4.3±1.5	34	4.5±1.7	32	4.3±1.4	32	4.3±1.5

Data are shown as means ± standard deviation. Abbreviations: Ex-Moderate, moderate intensity group; Ex-Vigorous, vigorous intensity group.

Table 2. Changes in body weight and composition outcomes after the intervention among the three groups including all participants that were assessed after 24 weeks of supervised exercise training.

	Intervention			Mean Difference (95% CI)			P value		
	Control (N=34) Median (SD)	Ex-Moderate (N=32) Median (SD)	Ex-Vigorous (N=32) Median (SD)	Ex-Moderate vs. Control	Ex-Vigorous vs. Control	Ex-Vigorous vs. Ex-Moderate	Ex-Moderate vs. Control	Ex-Vigorous vs. Control	Ex-Vigorous vs. Ex-Moderate
Weight (kg)	1.24 (2.73)	-0.40 (2.67)	-2.16 (4.61)	-1.56 (-3.94, 0.83)	-3.12 (-5.52, -0.71)	-1.57 (-4.03, 0.91)	0.342	0.007	0.375
Fat mass (kg)	0.57 (0.59)	-1.83 (0.62)	-3.27 (0.63)	-2.41 (-4.53, -0.28)	-3.85 (-5.98, -1.71)	-1.44 (-3.60, 0.71)	0.021	<0.001	0.315
Fat mass (%)	0.30 (0.50)	-2.71 (0.63)	-3.84 (0.63)	-3.00 (-5.18, 0.83)	-4.14 (-6.29, -1.98)	-1.13 (-3.32, 1.05)	0.004	<0.001	0.622
VAT (g)	10.73 (14.62)	-47.79 (15.44)	-77.26 (15.43)	-58.52 (-111.16, -5.89)	-87.99 (-140.61, -35.38)	-29.47 (-82.91, 23.96)	0.024	<0.001	0.540
Lean mass (kg)	0.75 (0.37)	1.79 (0.39)	1.70 (0.39)	1.05 (-0.28, 2.37)	0.95 (-0.37, 2.27)	-0.09 (-1.47, 1.27)	0.172	0.248	1.000
Lean mass (%)	0.83 (0.41)	1.93 (0.44)	1.82 (0.44)	1.10 (-0.37, 2.79)	0.99 (-0.49, 2.81)	-0.11 (-1.55, 1.38)	0.183	0.265	0.931
Legs lean mass (kg)	0.27 (0.13)	0.62 (0.15)	0.59 (0.16)	0.35 (-0.13, 0.93)	0.32 (-0.16, 0.96)	-0.04 (-0.52, 0.43)	0.179	0.201	0.975
Arms lean mass	0.08 (0.04)	0.19 (0.05)	0.18 (0.06)	0.11 (-0.05, 0.34)	0.10 (-0.06, 0.32)	-0.01 (-0.18, 0.14)	0.196	0.253	0.925

Abbreviations: SD, standard deviation; Ex-Moderate, moderate intensity group; Ex-Vigorous, vigorous intensity group; VAT, Visceral Adipose Tissue. P value of analysis of covariance analysis between groups with post hoc Bonferroni-corrected. The analyses were adjusted for baseline values.

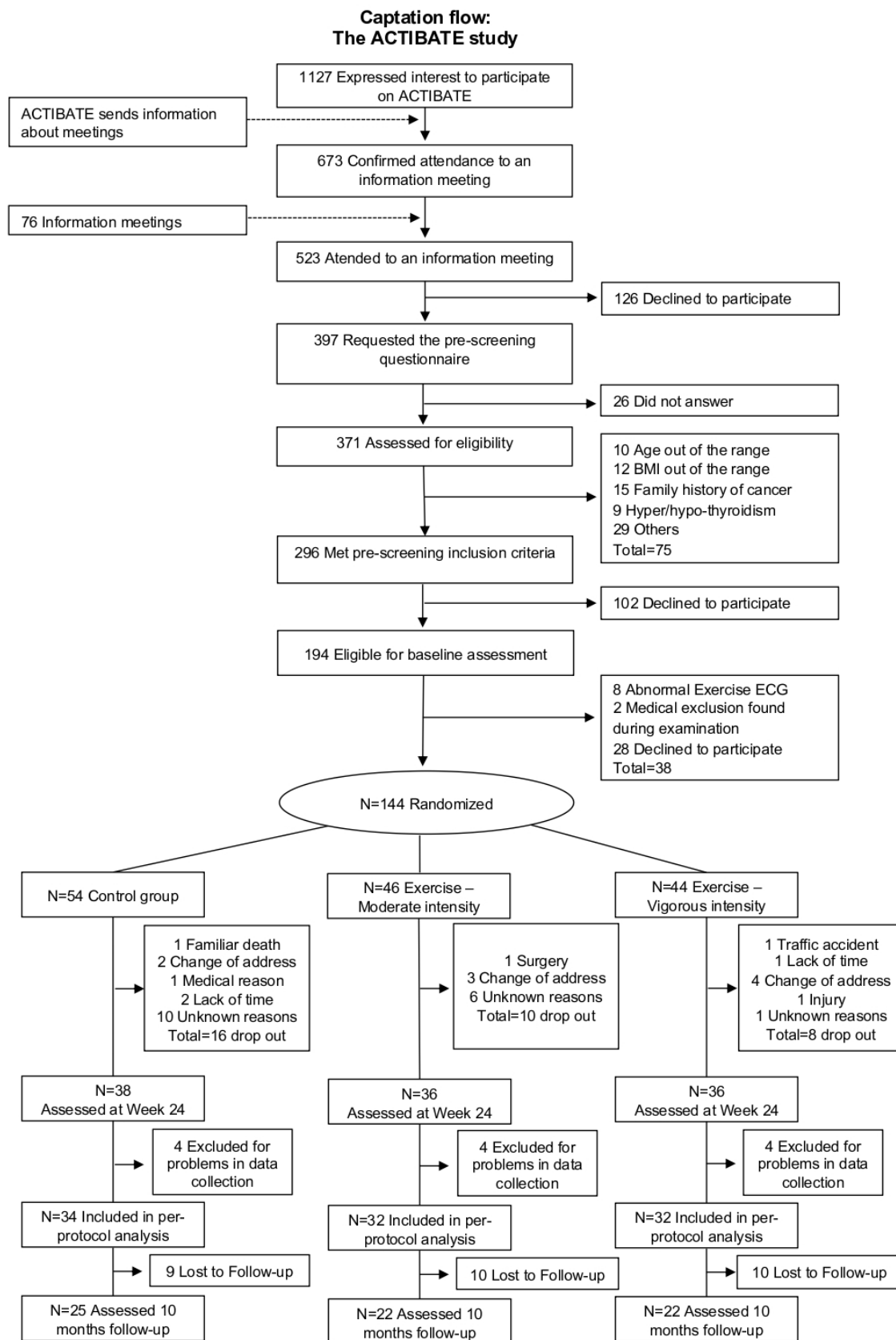
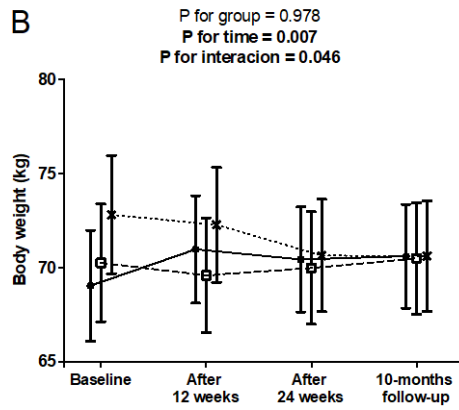
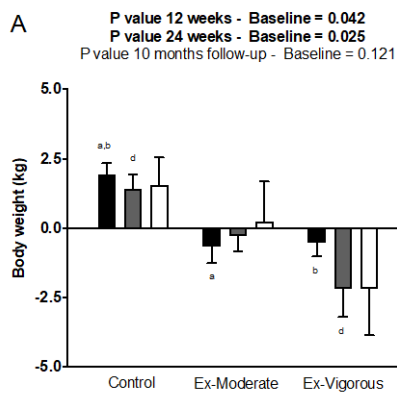


Figure 1: Flow-chart diagram. Abbreviations: BMI; body mass index, CDV; cardiovascular, ECG; electrocardiogram.



● Control
 ◻ Moderate
 ✕ Vigorous

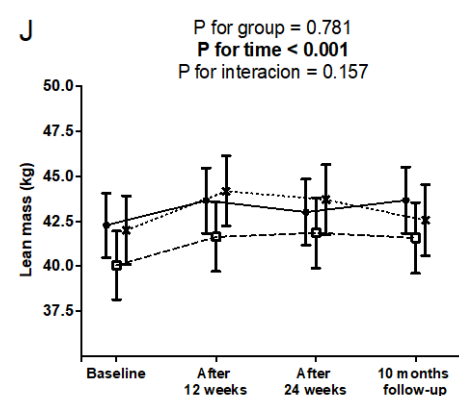
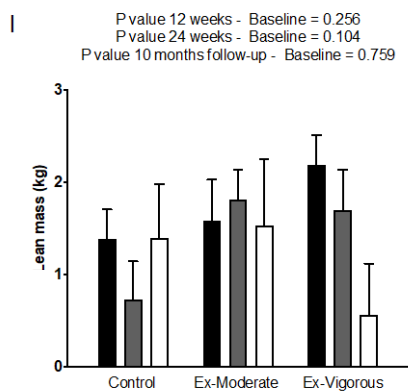
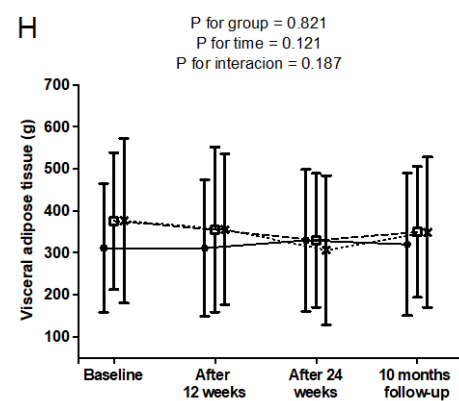
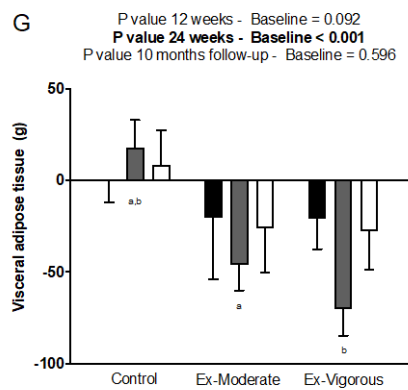
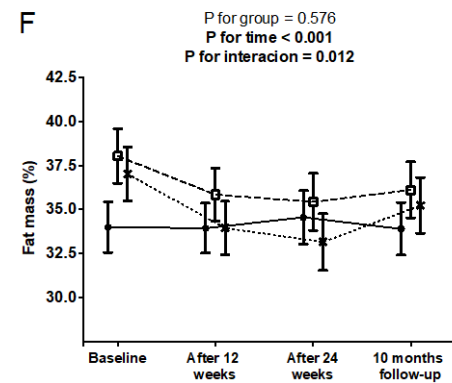
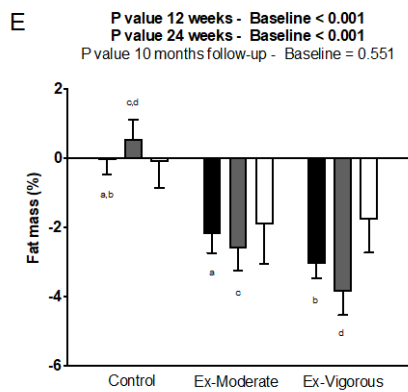
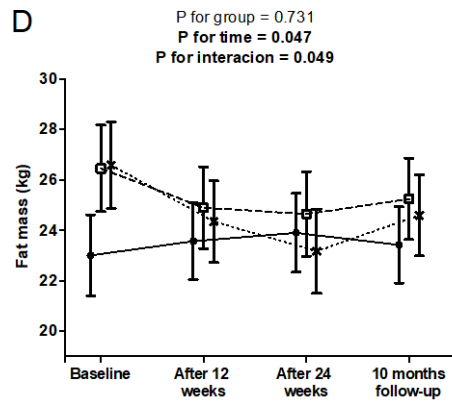
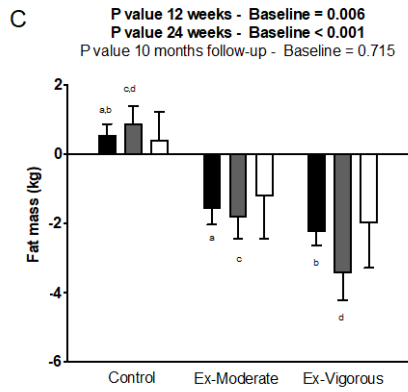


Figure 2. Changes in body weight (A and B), fat mass (C and D), fat mass percentage (E and F), visceral adipose tissue mass (G and H) and lean mass (I and J) at baseline, after 12 weeks, after 24 weeks and 10 months follow-up of the intervention among the three groups applying the per-protocol analysis. Data are shown as means \pm standard error. P value of analysis of covariance adjusting by baseline values, with post hoc Bonferroni-corrected (similar letters indicate significant differences) between after 12 weeks (black bars; n=98), after 24 weeks (grey bars; n=98), and after 10 months follow-up (white bars; n=71) of the intervention compared with baseline values, respectively (Panels A, C, E, G, and I). P values (time, group, and interaction [time x group]) obtained from mixed-effects regression models analyses (Panels B, D, F, H, and J). Abbreviations: Ex-Moderate, moderate intensity group; Ex-Vigorous, vigorous intensity group.

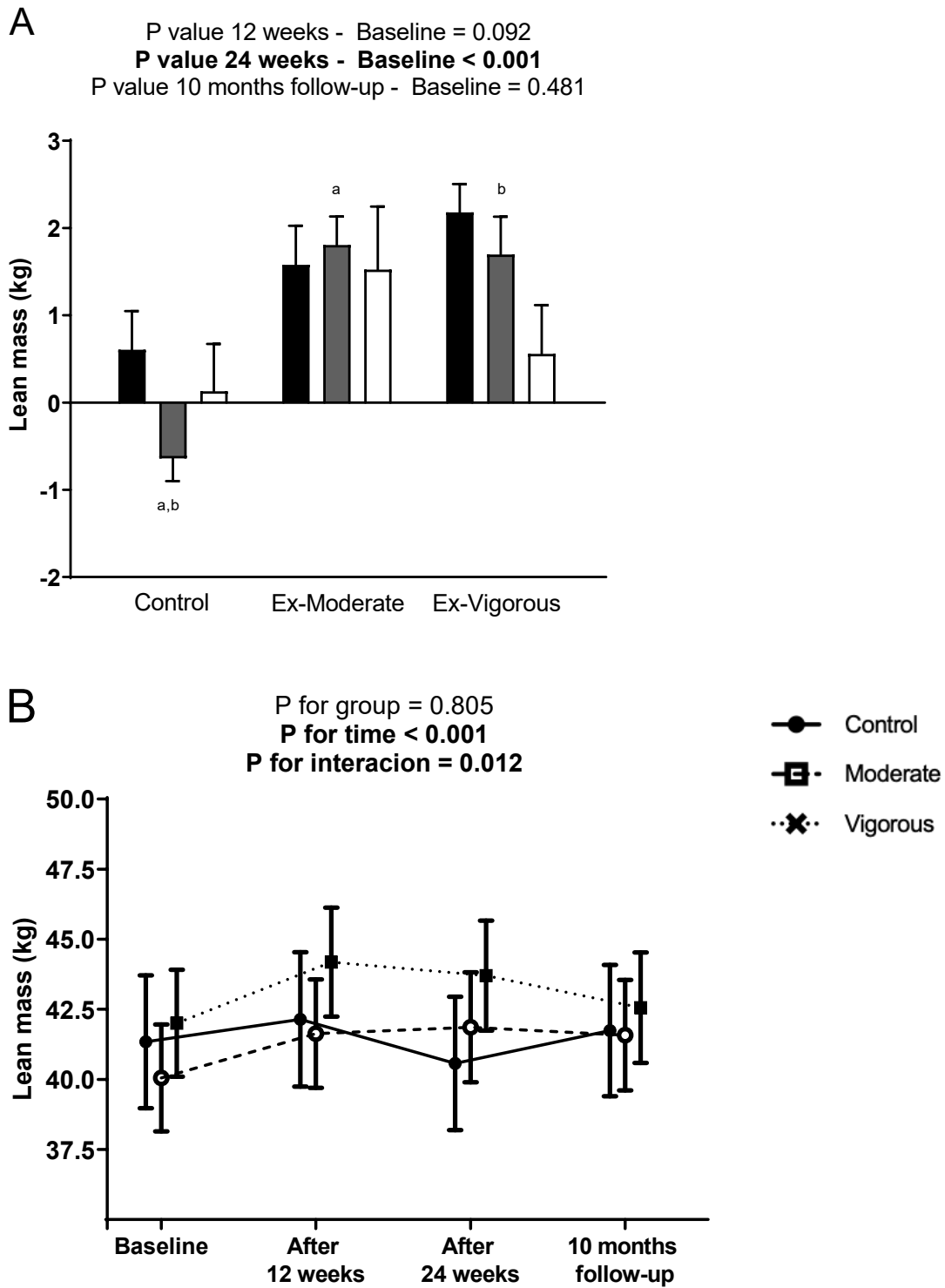


Figure 3. Changes in lean mass at baseline, after 12 weeks, after 24 weeks and 10 months follow-up of the intervention among the three groups excluding participants of the control group that reported to have performed an exercise program during the study and/or have modified their nutritional habits, and applying the per-protocol analysis. Data are shown as means \pm standard error. P value of analysis of covariance adjusting by baseline values, with post hoc Bonferroni-corrected (similar letters indicate significant differences) between after 12 weeks (black bars; n=87), after 24 weeks (grey bars; n=87), and after 10 months follow-up (white bars; n=60) of the intervention compared with baseline values, respectively (Panel A). P values (time, group, and interaction [time x group]) obtained from mixed-effects regression models analyses (Panel B). Abbreviations: Ex-Moderate, moderate intensity group; Ex-Vigorous, vigorous intensity group.