

1 **Exercise training and weight loss, not always a happy marriage: single blind exercise trials in**  
2 **females with diverse BMI**

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22

23 **Abstract**

24 Individuals show high variability in body weight responses to exercise training. Expectations and  
25 motivation towards effects of exercise on body weight might influence eating behaviour and could  
26 conceal regulatory mechanisms. We conducted two single-blind exercise trials (4 weeks (study 1)  
27 and 8 weeks (study 2)) with concealed objectives and exclusion of individuals with weight loss  
28 intention. Circuit exercise training programs (3 times a week (45-90 min), intensity 50-90%  $\text{VO}_2\text{peak}$ ,  
29 for 4 and 8 weeks) were conducted. 34 females finished the 4 weeks intervention and 36 females  
30 the 8 weeks intervention. Overweight/obese (OV/OB) and lean (L) female participants' weight/body  
31 composition responses were assessed and fasting and postprandial appetite hormone levels (PYY,  
32 insulin, amylin, leptin, ghrelin) were measured pre and post intervention for understanding potential  
33 contribution to individuals' body weight response to exercise training (study 2). Exercise training in  
34 both studies did not lead to a significant reduction of weight/BMI in the participants' groups,  
35 however, lean participants gained muscle mass. Appetite hormones levels were significantly ( $p < 0.05$ )  
36 altered in the OV/OB group affecting fasting (-24%) and postprandial amylin (-14%) levels.  
37 Investigation of individuals' BMI responses using multiple regression analysis revealed that levels of  
38 fasting leptin, postprandial amylin increase, and BMI were significant predictors of BMI change  
39 explaining about 43% of the variance. In conclusion, tested exercise training did not lead to weight  
40 loss in female participants, while a considerable proportion of variance in body weight response to  
41 training could be explained by individuals' appetite hormone levels and BMI.

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46 **Keywords:** Exercise, obesity, body mass maintenance, energy regulation, hormones

47 **Introduction**

48 Exercise is often prescribed for weight loss (Donnelly et al. 2009). However, although weight loss is  
49 often reported (Ross et al. 2000, 2004), exercise training does not always result in weight loss and  
50 often reveals high individual variability in body weight changes (King et al. 2007, 2008, Barwell et al.  
51 2009). Possible causes of less than expected weight outcomes are suggested to be modified  
52 appetite, perceived reinforcement value of food and altered unstructured physical activity (Blundell  
53 et al. 2003, King et al. 2007, Church et al. 2009). Accordingly, the concept of compensators and non-  
54 compensators of negative energy balance has been established, although causes for individuals'  
55 responses are still debated (Finlayson et al. 2009). Energy balance, and therefore body weight, is  
56 regulated by mediators released from gastrointestinal apparatus, pancreas and fat tissue, as well as  
57 nutrients. Tonic and phasic signals provide important information about the energy status to the  
58 brain. Leptin and insulin, as well as possibly amylin, providing tonic information about energy status;  
59 ghrelin, as well as PYY (1-36, 3-36), GLP-1, CCK, and again amylin and insulin providing phasic signals  
60 direct to the hypothalamus but also to the hind brain (Suzuki et al. 2010). Moreover, the levels of  
61 response to hormonal changes are not restricted to satiety and hunger but expand to neuronal  
62 systems connected to hedonic responses, like the mesolimbic dopamine neurons towards leptin and  
63 insulin (Figlewicz 2003, Figlewicz and Benoit 2009) or ghrelin's involvement in reward processing  
64 (Jerlhag et al. 2007). Alterations on hormonal levels are shown to contribute to the regulation of  
65 energy balance if challenged by exercise training (Stensel 2010); with training PYY and ghrelin are  
66 more consistently found to be altered than others (Broom et al. 2009, Ueda et al. 2009, Kawano et  
67 al. 2013). A possible influencing factor in exercise training studies is the control of motivation and  
68 intention of individuals to restrain their food intake, even if this may not be wanted by the  
69 experimenters. It is possible that some studies are biased towards weight loss based on the  
70 recruitment of participants who may be motivated to lose weight and not naïve towards study aims  
71 and objectives. To investigate possible mediators influencing individuals' weight loss response to  
72 exercise we conducted two single blind exercise training studies, one lasting 4 weeks (study 1) and

73 the other lasting 8 weeks (study 2). Group-based circuit training exercises were performed at 50-95%  
74 VO<sub>2</sub>peak, 3 times a week, for 45-90 min. Energy intake was *ad libitum* in both studies, which were  
75 designed with the intention of avoiding the formerly mentioned influence of motivation to lose  
76 weight. Thus, aims and objectives were concealed from the participants and spurious objectives  
77 were provided. Females over a wide range of BMI were recruited as participants and individuals who  
78 expressed an intention to lose weight were excluded. In the first study (4 weeks), a randomized  
79 control design was used and body characteristics and composition, as well as cardiovascular fitness  
80 were measured pre and post training. In the second study (8 weeks), fasting and postprandial blood  
81 samples were taken for measurements of appetite hormones and metabolites, body composition,  
82 cardiovascular fitness, and resting metabolic rate assessed pre and post intervention. We  
83 hypothesized that a) females with overweight/obesity and leanness would regulate their body  
84 weight successfully leading to no weight/BMI changes after the training interventions; b) measured  
85 appetite hormones levels (PYY, insulin, amylin, leptin, ghrelin) could be used to explain individuals'  
86 variance in BMI changes; c) hormone levels would be affected by exercise training leading to  
87 reduced levels of appetite suppressing hormones.

88

## 89 **Materials and methods**

90 The two studies were approved by Bangor University ethics committee and the North Wales  
91 Research Ethics Committee – West (Betsi Cadwaladr University Health Board – REC No 11/WA/0321  
92 and 12/WA/0118). All participants were given written and verbal information and participants  
93 provided written informed consent.

### 94 **Participants and studies design**

95 For both studies, sedentary females were recruited. In study 1, 40 females were recruited for a 4  
96 weeks training intervention, with 34 finishing the study. Participants were randomly allocated to an

97 exercise training group or a control group. In study 2, 56 females were recruited for an 8 weeks  
98 training intervention with 36 females completing. For both studies, recruitment was performed  
99 using emails to students and employees of Bangor University and posters in the Bangor area. To  
100 conceal the aims and objectives of the research, potential participants were informed that the study  
101 investigated *the influence of exercise training on cognitive performance and cardiovascular fitness*. In  
102 study 2, an incentive for taking part was the reimbursement for effort with a pair of trainers up to  
103 £100 value. The element of deception in both studies was achieved using a computer based  
104 cognitive sorting task for measuring reaction times in recognising combinations of pictures and  
105 words. Participant information sheets were written according to the spurious objectives, and any  
106 questions arising were answered by researchers accordingly. Participants were debriefed after the  
107 intervention.

108 Potential participants were selected to take part in the study based on their responses to a pre-  
109 screening questionnaire assessing health, physical activity, general diet habits (i.e. restrictive diet).  
110 To avoid participants' bias towards weight loss and potential dieting, we used Aizen's theory of  
111 planned behaviour (Ajzen 1991) as a framework for including/excluding participants based on  
112 current intention to lose weight (Sørensen et al. 2005). Participants were aged between 18 and 40;  
113 BMI categories were lean (L) < 25 kg/m<sup>2</sup> and overweight/obese (OV/OB) > 25 kg/m<sup>2</sup>; healthy;  
114 sedentary; not following any type of specialised diet; and having not stated an intention to lose  
115 weight.

116 Exercise sessions were circuit based (e.g. running on the spot, lunges, star jumps, sit-ups, press-ups  
117 and squats) for both studies and completed 3 times a week. Length of sessions was 60 minutes in  
118 study 1, and between 40 – 90 minutes in study 2, dependent upon the intensity of exercise required  
119 to achieve equal exercise energy expenditure across two training groups (descriptions follows). All  
120 sessions were completed in small training groups (5-10 participants) and supervised by 3 members  
121 of the research team. Participants trained in groups according to their BMI group (L or OV/OB). In

122 study 1, after randomized distribution into control and exercise group, individuals trained on a target  
123 heart rate representing 70-80% of their heart rate at  $\dot{V}O_{2peak}$ . The control group did not take part in  
124 any exercise training. In study 2, to include the influence of exercise intensity into the design,  
125 participants were randomly assigned to two exercise intensities moderate (50-60%  $\dot{V}O_{2peak}$ ) (L and  
126 OV/OB) and high intensity (80-90%  $\dot{V}O_{2peak}$ ) (L and OV/OB) training groups. Exercise intensity was  
127 used as a continuous variable based on heart rate recordings as well as a covariate in the statistical  
128 analysis due to high variability of achieved target heart rates in the groups. Heart rate was  
129 continuously recorded throughout all sessions and an approximation of energy expenditure was  
130 calculated based on  $\dot{V}O_{2peak}$  assessment. Training intensity was controlled by a telemetric heart  
131 rate monitoring system (Activio, Activio Sport System, Sweden) displaying the live heart rates of  
132 each participant. HR data were analysed to calculate mean exercise intensity and estimates of  
133 energy expenditure throughout the 8 weeks training (study 2) to achieve a matched total exercise  
134 energy expenditure across groups.

### 135 Anthropometry

136 Body mass and composition were measured using a beam scale (Seca, Germany) and dual-energy x-  
137 ray absorptiometry (DXA; QDR 4500, Hologic, Bedford, MA, USA).

### 138 Resting metabolic measurements

139 In study 2, after 12 hour overnight fast participants, having refrained from exercise for 48 hours,  
140 resting metabolic rate ( $\text{kcal}\cdot\text{min}^{-1}$ ) and respiratory exchange ratio (RER;  $\dot{V}CO_2/\dot{V}O_2$ ) were measured  
141 by indirect calorimetry (Oxycon Pro, Erich Jaegar, Germany) in a supine position for 30 minutes;  
142 heart rate (Polar RS800CX, Polar Electro Oy, Kempele, Finland) was also recorded.

### 143 Blood sampling and analysis

144 In study 2, under both overnight-fasting and postprandial conditions 12ml of venous blood was  
145 collected from the antecubital vein. Glucose was measured by the Accu-Chek Aviva glucose meter

146 (Accu-Chek® Aviva, Mannheim, Germany). For further measurements, plasma was aliquoted, frozen  
147 and stored at -80°C. Hormone measurements were carried out by enzyme-linked immunosorbent  
148 assay (ELISA) and plate reader (Fluostar Omega, BMG Labtech, Germany). ELISAs were carried out to  
149 measure amylin (Millipore, St. Charles, MO, USA) (intra assay CV: 12% ), insulin (Merckodia, Uppsala,  
150 Sweden) (intra assay CV: 7%), leptin (BioVendor Research and Diagnostic Products, BioVendor –  
151 Laboratorni medicina a.s., Czech Republic) (intra assay CV: 7% ), total ghrelin (Millipore; St. Charles,  
152 MO, USA) (intra assay CV: 4%), and PYY (Millipore Corporation, Billerica, MA, USA) (intra assay CV:  
153 12%). The Homeostasis Model Assessment version 2 (HOMA2) ([www.dtu.ox.ac.uk/homacalculator/](http://www.dtu.ox.ac.uk/homacalculator/))  
154 was used to calculate beta cell function, insulin resistance and insulin sensitivity. All samples were  
155 batch analysed and assayed in duplicate.

#### 156 Test meal

157 In study 2, to analyse potential influence of chronic and phasic appetite hormone changes on  
158 individual BMI alterations, participants were given a liquid test meal (Resource® Energy Vanilla  
159 200ml, Nestle, Switzerland) following overnight fast according to a modified protocol by Kraemer et  
160 al. (2011). The meal provided 300kcal of which 55% was carbohydrate, 30% fat and 15% protein. This  
161 test meal was chosen to avoid variability in intake composition and processing known from more  
162 complex meals. Blood samples were taken prior to the test meal at fasting state and precisely 1 hour  
163 after consumption. Timing of blood sampling was chosen due to former experiments selecting the  
164 time point with the strongest correlation between appetite hormone levels and BMI-based body  
165 type. Significant ( $p<0.05$ ) correlations between BMI and appetite hormone levels at fasting (F),  
166 postprandial (PP) levels and alterations (CH) were found for insulin (F,  $\rho=0.49$ ; PP,  $\rho=0.37$  ),  
167 amylin (F,  $\rho=0.49$ ; CH,  $\rho=-0.48$  ), PYY (CH,  $\rho=-0.33$ ), ghrelin (CH,  $\rho=0.43$ ), leptin (F,  $\rho=$   
168 0.59).

#### 169 Peak oxygen consumption

170 For both studies, peak oxygen uptake ( $\dot{V}O_{2PEAK}$ ; ml.kg<sup>-1</sup>.min<sup>-1</sup>) was measured on a cycle ergometer  
171 (Corival 400, Lode, Groningen, Netherlands) using a graded exercise protocol with 1 minute stages  
172 (20 watts steps), until exhaustion. Oxygen and carbon dioxide were measured by a metabolic cart  
173 (Oxycon Pro, Erich Jaegar, Germany). Heart rate (Polar RS800CX, Polar Electro Oy, Kempele, Finland)  
174 and ratings of perceived exertion (Borg 1973) were collected at the end of every stage and at point  
175 of exhaustion.  $\dot{V}O_{2PEAK}$  was achieved when one of three criteria was met: RER greater than 1.1, RPE  
176 of 20 or cycling cadence less than 60rpm. Control subjects in study 1 were not tested for  $\dot{V}O_{2PEAK}$ .

177 Statistical analysis

178 All statistical analyses were performed using IBM SPSS Statistics 20. Data were analysed either by  
179 one-way ANOVA (baseline characteristics), ANCOVA using exercise intensity as a covariate or by  
180 mixed model ANOVA and appropriate post hoc analysis, after assumptions had been met and  
181 outliers removed. Pearson's and Spearman's rho correlations were used to analyse relationships  
182 between variables. Multiple regression analyses using the enter and backward methods were  
183 performed on variables of interest. All data are reported as means and  $\pm$  standard deviation.

184 Statistical significance was set at  $p < 0.05$ .

185

## 186 Results

187 In the first study, 34 female participants of the 40 recruited finished the intervention. Mixed model  
188 ANOVA with repeated measures revealed that there were no significant alterations in weight/BMI  
189 after the 4 weeks, neither in the exercise training group nor in the non-exercising control group  
190 (Table 1). Consequently, exercise related energy expenditure was compensated and body  
191 weight/BMI was maintained. Further analysis of body composition showed that there was a  
192 significant reduction in body fat [%] in the exercise group, however, this effect was only seen in the  
193 lean participants who lost about 0.5 kg fat (significant effect of time ( $p = 0.018$ ), interaction of time x



194 trial (control/exercise) ( $p=0.041$ ), and interaction of time x baseline body fat [%] ( $p=0.046$ )), (Table  
195 1). Moreover, an increase in lean mass (kg) was significant only in the lean participants of the  
196 exercise group, who gained about 1 kg lean mass (increase of lean mass over time ( $p=0.009$ ),  
197 interaction of time x baseline fat percentage [%] ( $p=0.028$ ) and time x trial (control/exercise  
198 ( $p=0.05$ )), (Table 1). Individual alterations in body characteristics over the 4 weeks intervention  
199 period are depicted in Figure 1; positive effects on body composition were restricted to lean  
200 participants of the exercise group but without alteration of weight/BMI.

201 The second study used principally the same experimental design but omitting a non-exercising  
202 group; the training program was performed for 8 weeks. Additionally, exercise energy expenditure  
203 was matched across participants using a wider range of training intensities (50-90% $VO_{2peak}$ ).  
204 Training intensity was implemented as a covariate to investigate its possible influence on weight and  
205 body composition. This was suggested based on outcomes of study 1 where body composition  
206 changes were restricted to lean participants who trained on higher absolute intensity. Moreover,  
207 fasting and postprandial blood samples were collected for the analysis of appetite hormones and  
208 metabolites pre and post intervention. The design was chosen to confirm outcomes of study 1 with a  
209 further focus on the investigation of underlying factors responsible for individual weight/BMI  
210 responses to exercise in lean and overweight/obese females.

211 From the 56 recruited females for the 8 weeks training program, 36 females finished the study.  
212 Baseline body characteristics and blood parameters of the participants are given in Table 2. OV/OB  
213 participants had higher ( $p < 0.05$ ) levels of BMI, weight, fat mass, lean mass, and RMR as well as  
214 lower relative  $VO_{2peak}$  compared with L individuals (Table 2).

215 Training compliance was ~85 % across the training groups with no difference between groups; heart  
216 rate based estimates of total exercise energy expenditure, amounting to ~3400 kcal after 8 weeks,  
217 and was matched across the groups (Table 3). Moreover, mean training intensity in percent heart  
218 rate reserve was about 65% with no difference between lean and OV/OB groups (Table 3).

219 Mixed model ANOVA with body type (BMI groups) as between factor and training intensity as  
220 covariate revealed that 8 weeks training did not lead to significant alterations of BMI/weight in  
221 either group (no significant main effect of time, or interactions of time x group) (Table 3); hence,  
222 both groups compensated the exercise energy expenditure over the training period confirming  
223 outcomes of study 1. In terms of body composition changes, females of the lean group lost body fat  
224 while participants of the OV/OB group remained unaltered after the training period (no significant  
225 time effect was reported for body fat [%] change but a significant ( $p=0.008$ ) interaction of time x  
226 body type). Moreover, lean mass (kg) was not affected (non-significant time effect) but there was a  
227 significant interaction time x training intensity ( $p=0.025$ ) supporting the hypothesis that lean mass  
228 changes have been influenced by training intensity (Table 3). A further splitting of the data (Table 4)  
229 in moderate and high intensity training groups without consideration of BMI shows that the higher  
230 intensity group tended to gain more lean mass than the moderate exercise group. Moreover, a  
231 significant correlation ( $R=0.458$ ;  $p=0.006$ ) between training intensity and  $\dot{V}O_{2PEAK}$  showed that  
232 individuals with higher cardiovascular fitness tended to train harder.

233 In summary, the second study confirmed that lean and OV/OB females compensate exercise induced  
234 energy expenditure without losing weight but positive body composition changes were more  
235 apparent in lean participants being possibly related to training intensity.

236 To further investigate individuals' weight/BMI response to training (individuals' post intervention  
237 changes in BMI and body composition are shown in Figure 2), we analysed fasting and postprandial  
238 blood samples.

239 ANOVA analysis of pre intervention levels of the two groups revealed significant differences in  
240 fasting levels for leptin, PYY, insulin, and amylin between groups (Table 5). Moreover, postprandial  
241 increases in amylin and PYY were significantly different between L and OV/OB groups (Table 5). After  
242 8 weeks exercise training, fasting and postprandial levels of amylin were significantly reduced in the  
243 OV/OB group but not in the L group (no significant main effect of time, significant interaction of time

244 x body type,  $p < 0.001$  for fasting and postprandial levels,  $p = 0.004$ ) (Table 5). The postprandial  
245 increase of amylin, which was significantly different between groups, was unaltered after the  
246 training revealing an unchanged higher increase of amylin after the test meal in L group females  
247 compared with females of the OV/OB group (Table 5). Multiple regression analysis showed that  
248 postprandial amylin levels after the intervention were determined ( $R^2 = 0.34$ ,  $p = 0.002$ ,  $n = 33$ ) by  
249 fasting glucose levels ( $\beta = 0.35$ ,  $p = 0.027$ ) and postprandial increase in glucose ( $\beta = 0.50$ ,  $p = 0.002$ ).  
250 Fasting and postprandial levels of insulin, leptin, PYY, total ghrelin were unchanged after exercise  
251 training (no significant main effect and interactions) (Table 5).

252 To further associate hormonal levels with individuals' BMI response to exercise (see also figure 2),  
253 we performed multiple regression analysis (enter method) using appetite hormone levels as  
254 predictor variables and body characteristics for post intervention BMI changes. Analysis led to a  
255 significant model for the BMI change of participants who finished the training; the model used post  
256 intervention levels of leptin ( $\beta = 0.59$ ,  $p = 0.002$ ) and postprandial amylin change ( $\beta = -0.37$ ,  $p = 0.03$ ), and  
257 pre-intervention BMI ( $\beta = -0.44$ ,  $p = 0.02$ ) as predictor variables. The three variables explain 43% of the  
258 variance of the BMI alterations ( $R^2 = 0.43$ ,  $p = 0.002$ ,  $n = 30$ ) after training. Other hormone parameters  
259 did not lead to significant model improvements.

## 260 Metabolic alterations

261 There were significantly higher levels in insulin sensitivity, beta cell function and lower insulin  
262 resistance in the L- than in the OV/OB group. However, comparisons of HOMA 2 parameters  
263 revealed no significant alterations after 8 weeks training. Additionally,  $\dot{V}O_2$  peak, RER, RMR, and  
264 fasting glucose levels were not significantly changed (Table 3).

265

## 266 Discussion

267 We conducted two exercise training interventions with sedentary females with concealed aims and  
268 objectives of the study and excluding participants who expressed an intention to lose weight. To our  
269 knowledge, this is the first exercise training study which tried to achieve *ad libitum* conditions for  
270 participants whilst avoiding the influence of explicit motivation towards weight loss. Both  
271 interventions did not lead to significant weight loss/BMI change in both OV/OB and L groups after 4  
272 and 8 weeks training. This finding is consistent with our first hypothesis and we interpret this as  
273 indicative of intact weight regulation over the periods of the exercise training, even in females with  
274 high BMI (e.g. overweight/obesity). This outcome, considering the mean weight changes, as well as  
275 individual weight responses to exercise, is dissimilar to results published earlier (King et al. 2007,  
276 2008). For example, King et al. (2008) reported considerable weight loss with high variability  
277 amongst overweight/obese participants and outcomes were skewed towards weight loss. This  
278 suggests that BMI/weight alterations in comparable training studies might be partially driven by  
279 participants' intention to lose weight with concomitant consequences for eating behaviour rather  
280 than a singular effect of exercise. Additionally, recent work showed that the window for a  
281 satisfactory increase in total energy expenditure is narrow; in a large, diverse population sample it  
282 was shown that only about 7-9% of the variance in total energy expenditure was explained by  
283 physical activity (Pontzer et al. 2016). These authors assume that homeostatic regulation not only  
284 affects weight but also total energy expenditure.

285 Our study results on group level (i.e. no weight change over time), though, do not explain the  
286 individuals' weight response to training which varied strongly from considerable weight loss to  
287 weight gain, a consistent finding in studies which lead to the concept of compensators and non-  
288 compensators (King et al. 2008). As mentioned before, body weight is influenced by homeostatic and  
289 hedonic mechanisms, with some authors suggesting that humans are more prone to be driven by  
290 hedonic regulation (Berthoud 2011). Indeed, exercise energy depletion could increase the incentive  
291 salience of food, like it is known from fasting (Berthoud 2011) and increasing hunger levels have  
292 previously been reported following exercise training (King et al. 2009). However, it was suggested

293 that alterations in food reward after exercise bouts are not influenced by exercise training and the  
294 reward response seems to be more trait-like. Finlayson et al. (2011) did not find alterations in  
295 wanting and liking of foods after 12 weeks training but participants who lost weight (responders)  
296 had a lesser increase in food reward after a bout of exercise than participants who reduced weight  
297 less than predicted (non-responders). Additionally, in our study, participants, not having the  
298 objective to lose weight, could have responded to the exhaustion and sensation of effort related to  
299 exercise in a self-rewarding manner with the selection of high palatable foods. Furthermore, poor  
300 judgement of caloric expenditure could have reduced existing diet restraint. Clearly, these possible  
301 factors might have contributed to the variance in the weight outcomes in our study. However, due  
302 to our study design we were not able to collect data about any alterations in food reward. On the  
303 other hand, it is known that both regulatory processes are heavily interlinked and difficult to  
304 separate; in particular appetite hormones are repeatedly shown to influence 'liking' and 'wanting' or  
305 reward perception, as well as influencing energy intake and energy metabolism (Volkow et al. 2011).  
306 While we gathered no information about the individuals' motives of eating in our study, we still  
307 gathered information about appetite hormones responses at fasting and postprandial levels to  
308 analyse their possible contribution to the variability of weight/BMI changes after the exercise  
309 training intervention. Post intervention, most of the tested appetite hormones revealed no  
310 alterations in both groups maintaining the differences detected at baseline. Nonetheless, we found  
311 significant alterations of amylin at fasting and postprandial levels in the OV/OB group, while the L  
312 group revealed no changes after the 8 weeks training intervention. Reports about alterations in  
313 amylin levels in response to exercise training are sparse; Izadpanah et al. (Izadpanah et al. 2012) and  
314 Roberts et al. (2013) reported a reduction of amylin in response to a combined diet exercise  
315 intervention in children with obesity for 14 days. Additionally, acute responses to exercise bouts  
316 with a reduction of amylin after prolonged exercise bouts (Kraemer et al. 2011) and increase in  
317 higher intensity bouts (Kraemer et al. 2002) were recently shown. Mechanistically, amylin expression  
318 in beta cells was recently shown to respond directly to glucose availability via carbohydrate-

319 response-element-binding-protein (ChREBP) and thioredoxin-interacting-protein (TXNIP) (Jing et al.  
320 2014). Indeed, our data revealed that amylin levels were significantly influenced by fasting levels and  
321 postprandial increase of glucose supporting this possible connection between amylin levels and  
322 altered glucose availability. Moreover, a positive associations between postprandial amylin levels  
323 and fasting glucose levels at post intervention was particular strong ( $r=0.625$ ,  $p=0.02$ ) in OV/OB  
324 group which highlights a possible connection between glucose availability and amylin levels. Clearly,  
325 fasting glucose levels can be influenced via sugar/carbohydrate intake (Sartor et al. 2013) as well as  
326 exercise (Sartor et al. 2010). Theoretically, a stronger depletion in glycogen storage during exercise  
327 in OV/OB individuals who might have more preferred carbohydrate utilization during exercise could  
328 have reduced glucose availability and could have led to reduced amylin levels with consequences for  
329 appetite and possible compensatory food intake.

330 Participation in exercise is often driven by a desire to lose weight (Teixeira et al. 2012). However,  
331 individual physiological differences may confound attempts to lose weight. In our study, observed  
332 amylin alterations contributed to the individual weight outcomes after the intervention. Indeed, our  
333 multiple regression analysis showed that hormone levels of leptin and postprandial amylin increase  
334 were best predictors for BMI changes (about 43% of BMI change variance explained). Leptin is  
335 known to be the most important tonic signal of fatness and mainly sensed in the hypothalamus for  
336 the intrinsic drive to eat and consequently for the regulation of body weight and energy expenditure  
337 (Blundell and Gillett 2001); therefore the contribution of leptin levels in the model is not  
338 unexpected. Additionally, leptin's links towards perceptual response to food was recently  
339 established identifying fasting leptin levels as a determinant of food reward (Hopkins et al. 2014).  
340 However, the strong contribution of amylin for the model is noteworthy. Amylin is known to play a  
341 role as a satiogenic signal, inhibits gastric emptying, and possesses glucoregulatory functions;  
342 agonists are well established in supporting weight loss in people with obesity (Smith et al. 2007).  
343 Moreover, amylin and leptin are shown to share important functions in the hindbrain and  
344 hypothalamus; it is suggested that amylin enhances leptin signalling and lead to transient alteration

345 of leptin responsiveness threshold (Trevaskis et al. 2010). Decreased amylin levels (postprandial and  
346 fasting) could increase leptin responsiveness threshold and could have led to increased energy  
347 intake in response to exercise training. Consequently, participants who displayed a combination of  
348 high levels of leptin and low postprandial increase in amylin were more prone to weight gain during  
349 exercise training. However, further work needs to support this interpretation.

350 Our work has several limitation; firstly, the selection of appetite hormones measured in this study  
351 does not exclude the importance and possible contribution of other hormones to the weight  
352 response in our study. Clearly, other hormones are consistently shown to be affected by training.  
353 Exercise training type, intensity, and duration are certainly factors that could influence outcomes in  
354 studies; besides the involvement of restricted dieting. Moreover, knowledge about altered food  
355 preference over the training period in terms of caloric density, macronutrient amounts and  
356 composition would have supported the interpretation of results largely. However, the need for not  
357 disclosing objectives of our study excluded the recording of precise food diaries and assessments of  
358 food liking, wanting and preference. However, our study used an ecological training programme  
359 which includes exercises and intensities commonly used in leisure centres or gyms. Finally, we used  
360 females only; consequently, we can't extrapolate findings towards males.

361 In summary, we have shown that under *ad libitum* condition 4 and 8 weeks exercise training did not  
362 result in weight loss in females over a wide range of BMI. Appetite hormone responses revealed  
363 decrease in amylin at fasting and postprandial levels, however this was restricted to  
364 overweight/obese participants. A large proportion of variance in BMI changes after training could be  
365 explained by postprandial amylin increase and leptin levels, pointing towards an important influence  
366 of amylin for weight regulation during exercise training.

### 367 **Perspective**

368 Exercise training is often performed with the objective of losing weight. However, individuals may  
369 face less than expected weight loss or even weight gain over an exercise training period. Clearly,

370 unrealistic expectations about the response of an individual to exercise training impairs exercise  
371 participation, in particular in population groups who could largely benefit on many other health  
372 levels other than weight loss. In our single blind exercise training study, excluding participants with  
373 weight loss intentions, females within a wide range of BMI, did not lose weight on group levels.  
374 However, individual weight gains or losses could be explained by appetite hormone levels. In  
375 particular, levels of amylin and leptin could explain a significant proportion (43%) of the variance in  
376 BMI changes post training. Our results highlight the need for individualized interventions tailored  
377 also to the physiological and not only to psychological characteristics of clients in weight loss  
378 programs.

379

### 380 **Acknowledgments**

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383

### 384 **Conflict of interest**

385 The authors declare no conflict of interest.

386

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508 Table 1: Participants characteristic pre and post 4 weeks exercise training (study 1)

Parameter (units)	L Exercise (n = 10)		OV/OB Exercise (n = 7)		L Control (n = 10)		OV/OB Control (n = 7)	
	Pre	Post	Pre	Pre	Post	Post	Pre	Post
Age (years)	22.4 ± 4.6		26.9 ± 3.9		22.5 ± 2.2		27.0 ± 4.8	
Weight (kg)	58.13 ± 6.27	58.66 ± 5.73	77.00 ± 9.85	77.2 ± 10.95	57.34 ± 9.78	58.22 ± 10.10	84.03 ± 5.26	83.53 ± 6.47
BMI (kg/m <sup>2</sup> )	22.70 ± 2.14	22.92 ± 2.09	31.12 ± 5.60	31.21 ± 5.99	21.22 ± 2.46	21.55 ± 2.70	30.67 ± 2.09	30.67 ± 1.95
Fat percentage (%)	32.60 ± 5.91	31.39 ± 5.84*	43.93 ± 6.43	42.54 ± 7.05	29.90 + 4.09	29.80 ± 4.54	37.26 ± 2.51	37.20 ± 4.00
Lean mass (kg)	37.49 ± 3.67	38.56 ± 3.85*	42.30 ± 4.81	42.51 ± 4.67	38.59 ± 6.08	39.19 ± 6.26	52.63 ± 1.92	52.28 ± 2.51
VO <sub>2</sub> PEAK (L/min)	1.87 ± 0.47	1.87 ± 0.36	2.07 ± 0.65	1.99 ± 0.51				
VO <sub>2</sub> PEAK (ml/kg/min)	32.47 ± 8.34	31.85 ± 6.33	26.63 ± 7.15	25.31 ± 6.26				

\*, significantly different to baseline

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517 Table 2: Anthropometric and metabolic parameters of participants at baseline (Study 2)

Parameters (units)	OV/OB (n=23)	L (n=11)
Age (years)	23.39 ± 5.70	24.55 ± 6.93
BMI (kg m <sup>-2</sup> )	30.27 ± 3.66 *	22.41 ± 2.14
Weight (kg)	82.78 ± 11.88 *	63.71 ± 5.60
Fat mass (%)	38.74 ± 4.88 *	29.32 ± 4.72
Lean mass (kg)	49.13 ± 5.44 *	43.32 ± 3.99
Fasting glucose (mmol l <sup>-1</sup> )	4.56 ± 0.42	4.51 ± 0.44
Total cholesterol (mmol l <sup>-1</sup> )	3.85 ± 0.83	3.59 ± 0.56
HDL (mmol l <sup>-1</sup> )	1.51 ± 0.47	1.68 ± 0.41
LDL (mmol l <sup>-1</sup> )	2.24 ± 0.71	1.75 ± 0.63
TG (mmol l <sup>-1</sup> )	1.06 ± 0.37	0.80 ± 0.00
VO <sub>2</sub> peak (l min <sup>-1</sup> )	2.64 ± 0.49	2.92 ± 0.56
VO <sub>2</sub> peak (l min <sup>-1</sup> kg <sup>-1</sup> )	32.58 ± 6.27 *	45.89 ± 0.85
RMR (kcal d <sup>-1</sup> )	1619.2 ± 318.9 *	1361.4 ± 178.9
RER	0.77 ± 0.06	0.79 ± 0.07

\* significant group difference p<0.05; High Density Lipoprotein, HDL; Low Density Lipoprotein, LDL; Triglycerides, TG; Resting Metabolic Rate, RMR; Respiratory Exchange Ratio, RER

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529 Table 3: Training parameters and alterations of anthropometric and metabolic characteristics of 8  
 530 weeks training study

Parameter (units)	OV/OB (n=23)	L (n=11)
Training Energy Expenditure (kcal)	3324.7 ± 1060.4	3194.2 ± 1344.0
Training intensity (Watt)	89.94 ± 36.13	78.84 ± 20.06
Training intensity (% Heart Rate Reserve)	60.47 ± 11.09	65.10 ± 11.98
Δ BMI (kg m <sup>-2</sup> )	0.15 ± 0.48	0.02 ± 0.33
Δ Weight (kg)	0.43 ± 1.69	0.08 ± 0.96
Δ Fat mass (%)	0.15 ± 1.43	-1.16 ± 1.12 #
Δ Lean mass (kg)	0.15 ± 1.23 †	0.61 ± 1.18 †
Δ Fasting glucose (mmol l <sup>-1</sup> )	0.08 ± 0.45	0.28 ± 0.40
Δ Total cholesterol (mmol l <sup>-1</sup> )	0.27 ± 0.64	0.23 ± 0.60
Δ HDL (mmol l <sup>-1</sup> )	-0.10 ± 0.23	0.05 ± 0.35
Δ LDL (mmol l <sup>-1</sup> )	0.25 ± 0.48	0.17 ± 0.50
Δ TG (mmol l <sup>-1</sup> )	0.12 ± 0.26	0.05 ± 0.18
Δ VO <sub>2</sub> peak (l min <sup>-1</sup> )	0.05 ± 0.41	-0.23 ± 0.32
Δ VO <sub>2</sub> peak (l min <sup>-1</sup> kg <sup>-1</sup> )	0.61 ± 5.10	-3.43 ± 4.74
Δ RMR (kcal d <sup>-1</sup> )	44.86 ± 250.95	116.57 ± 182.85
Δ RER	0.032 ± 0.08	0.024 ± 0.11

Δ represents changes from pre to post training; Significant (p<0.05) effect of group, \*; significant (p<0.05) interaction (group x time), #; interaction (training intensity x time), †

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539 Table 4: Alterations in anthropometric and metabolic parameters after 8 weeks moderate and high  
 540 intensity exercise training

Parameters (units)	Moderate Intensity (n=16)	Change (post –pre intervention levels)	High Intensity (n=18)	Change (post –pre intervention levels)
Age (years)	23.06 ± 5.27		24.35 ± 6.74	
BMI (kg m <sup>-2</sup> )	27.14 ± 4.75	0.11 ± 0.61	28.11 ± 5.17	0.01 ± 0.62
Weight (kg)	74.13 ± 11.85	0.33 ± 1.64	78.83 ± 14.50	0.02 ± 1.76
Fat mass (%)	35.39 ± 6.44	0.04 ± 1.34	35.84 ± 6.84	-0.81 ± 1.74
Lean mass (kg)	45.84 ± 5.14	-0.01 ± 1.14	48.39 ± 6.50	0.55 ± 1.26
Fasting glucose (mmol l <sup>-1</sup> )	4.37 ± 0.39	0.30 ± 0.46†	4.75 ± 0.36	-0.02 ± 0.34†
Fasting cholesterol (mmol l <sup>-1</sup> )	3.81 ± 0.76	0.31 ± 0.74	3.71 ± 0.76	0.15 ± 0.49
HDL (mmol l <sup>-1</sup> )	1.72 ± 0.44	-0.14 ± 0.30	1.40 ± 0.40	0.03 ± 0.22
LDL (mmol l <sup>-1</sup> )	2.02 ± 0.61	0.30 ± 0.54	2.10 ± 0.80	0.10 ± 0.43
TG (mmol l <sup>-1</sup> )	0.90 ± 0.18	0.12 ± 0.26	1.04 ± 0.41	0.08 ± 0.24
VO <sub>2</sub> peak (l min <sup>-1</sup> )	2.75 ± 0.53	-0.84 ± 0.47	2.72 ± 0.52	0.02 ± 0.32
VO <sub>2</sub> peak (l min <sup>-1</sup> kg <sup>-1</sup> )	38.06 ± 8.39	- 1.18 ± 5.94	36.00 ± 9.52	0.02 ± 4.43
RMR (kcal d <sup>-1</sup> )	1460.3 ± 219.1	102.9 ± 187.7	1629.4 ± 356.9	19.8 ± 266.3
RER	0.78 ± 0.06	0.01 ± 0.10	0.77 ± 0.06	0.04 ± 0.07

† significant interaction (intensity \* time) p<0.05; High Density Lipoprotein, HDL; Low Density Lipoprotein, LDL; Triglycerides, TG; Resting Metabolic Rate, RMR; Respiratory Exchange Ratio, RER

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547 Table 5: Appetite hormones and HOMA 2 parameters at baseline and after 8 weeks exercise training

	OV/OB (n=23)		L (n=11)	
	Pre	Post	Pre	Post
Fasting Leptin (ng ml <sup>-1</sup> )	36.25 ± 15.76 *	36.38 ± 16.40 *	16.00 ± 11.90	14.83 ± 12.52
Fasting Insulin (mU l <sup>-1</sup> )	7.52 ± 3.19 *	7.93 ± 3.69 *	4.34 ± 1.93	4.84 ± 2.61
Postprandial Insulin (mU l <sup>-1</sup> )	40.99 ± 19.43 *	47.48 ± 19.45 *	31.05 ± 17.35	38.15 ± 23.50
Postprandial Insulin Change (mU l <sup>-1</sup> )	33.46 ± 19.21	39.55 ± 19.41	26.27 ± 17.95	33.47 ± 23.59
Fasting Amylin (pg ml <sup>-1</sup> )	16.16 ± 3.85 *	12.25 ± 3.33 #	11.96 ± 6.20	11.66 ± 5.27
Postprandial Amylin (pmol l <sup>-1</sup> )	20.42 ± 3.64	17.55 ± 3.96 #	18.77 ± 7.89	20.96 ± 7.74
Postprandial Amylin Change (pmol l <sup>-1</sup> )	4.26 ± 2.76 *	5.35 ± 4.45 *	8.27 ± 4.69	9.64 ± 6.82
Fasting Ghrelin (pg ml <sup>-1</sup> )	677.0 ± 254.3	674.5 ± 244.8	797.4 ± 259.2	823.4 ± 321.7
Postprandial Ghrelin (pg ml <sup>-1</sup> )	452.3 ± 205.0	491.5 ± 216.4 #	566.3 ± 200.2	524.1 ± 179.2
Postprandial Ghrelin Change (pg ml <sup>-1</sup> )	-224.71 ± 126.72	-183.00 ± 93.74#	-231.13 ± 87.67	-299.32 ± 162.07
Fasting PYY (ng/ml)	146.85 ± 53.17	147.60 ± 64.92	118.70 ± 60.71	133.35 ± 50.89
Postprandial PYY (ng/ml)	206.73 ± 63.29	243.56 ± 54.90	227.38 ± 75.74	241.78 ± 81.36
Postprandial PYY Change (ng/ml)	62.87 ± 65.70*	95.96 ± 53.72	108.68 ± 40.30	108.43 ± 46.10
Beta Cell Function (%)	111.34 ± 31.14 *	109.91 ± 30.37 *	76.73 ± 22.90	73.33 ± 26.67
Insulin Sensitivity (%)	125.19 ± 55.43 *	118.19 ± 48.85 *	221.09 ± 113.02	200.09 ± 91.49
Insulin Resistance (IR)	0.95 ± 0.41 *	1.02 ± 0.48 *	0.55 ± 0.25	0.62 ± 0.34
Significant (p<0.05) effects of group, *, interaction (group x time), #				

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556 Figure 1: Individual changes in body characteristics in control and exercise group after 4 weeks  
557 exercise training. Black bars depict changes of overweight/obese individuals and empty bars of lean  
558 individuals.

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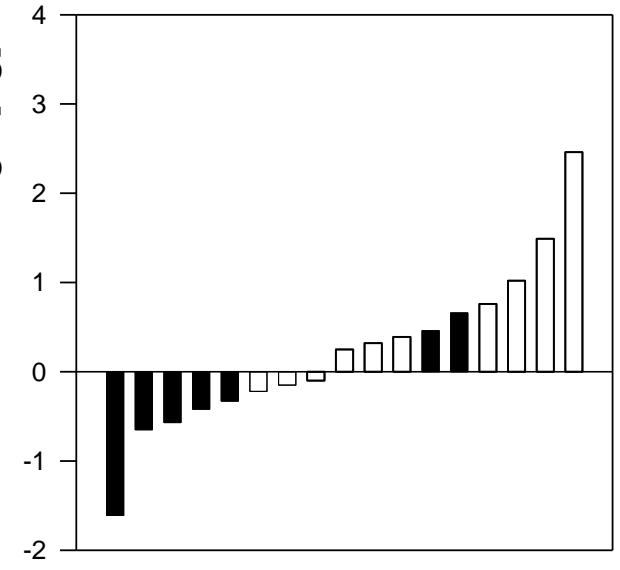
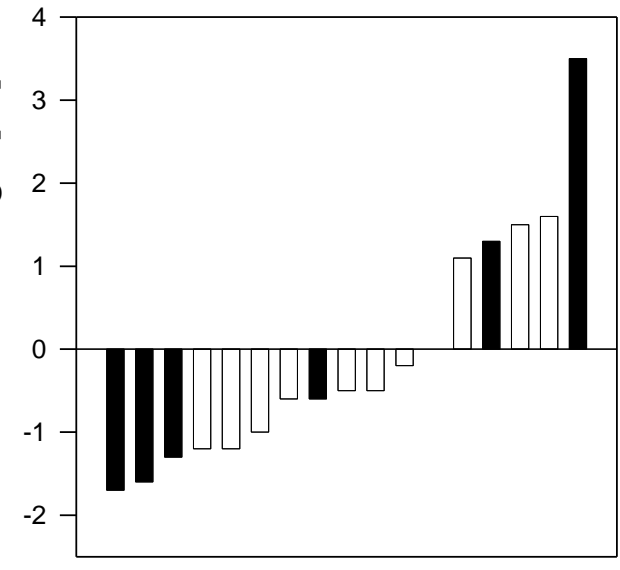
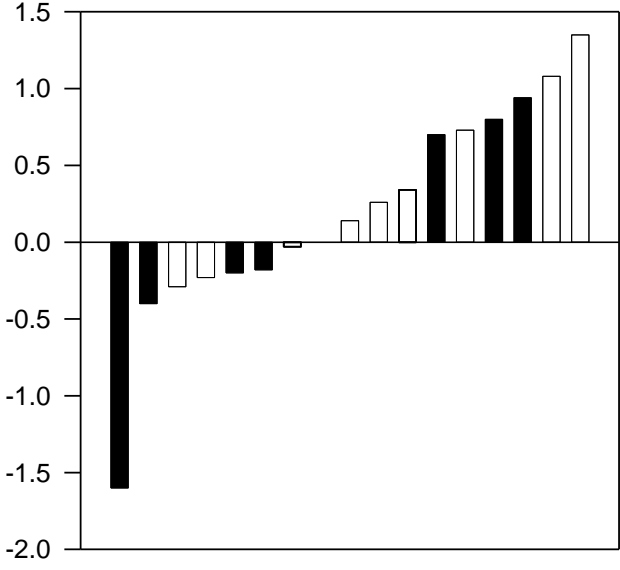
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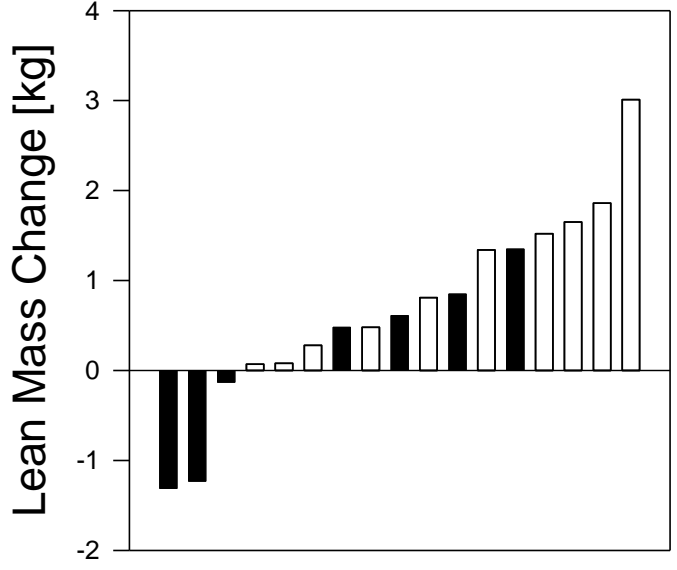
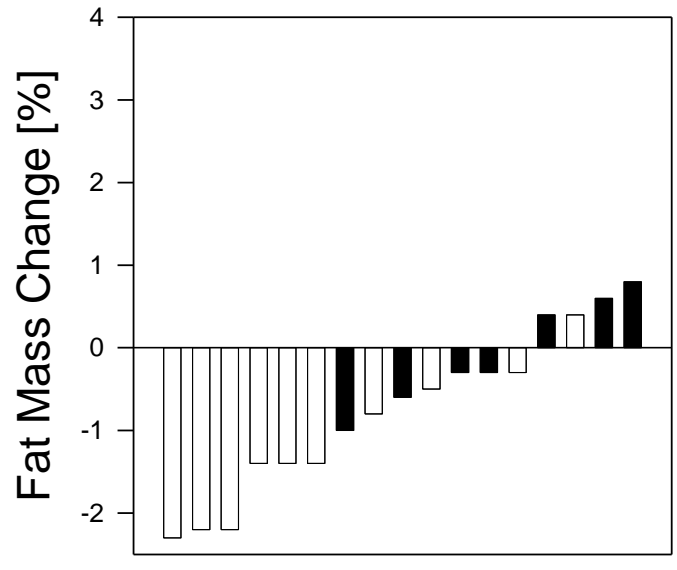
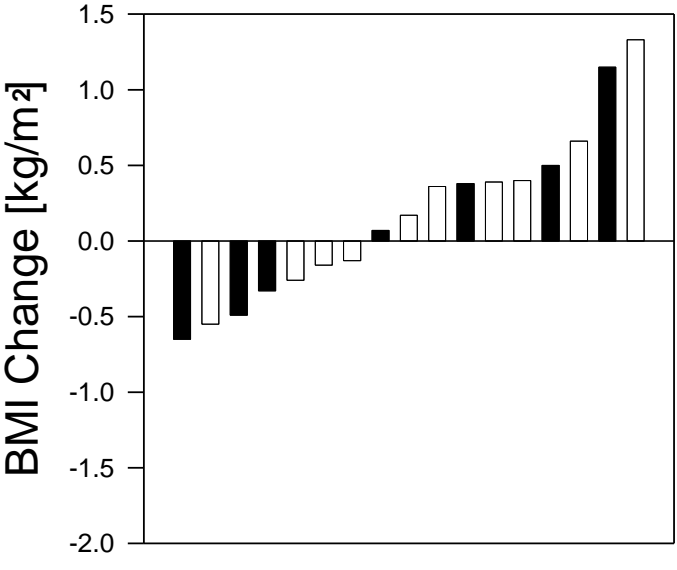
575

576 Figure 2: Individual changes in body characteristics after 8 weeks exercise training. Black bars depict  
577 changes of overweight/obese (OV/OB) individuals and empty bars of lean individuals (L).

### Control

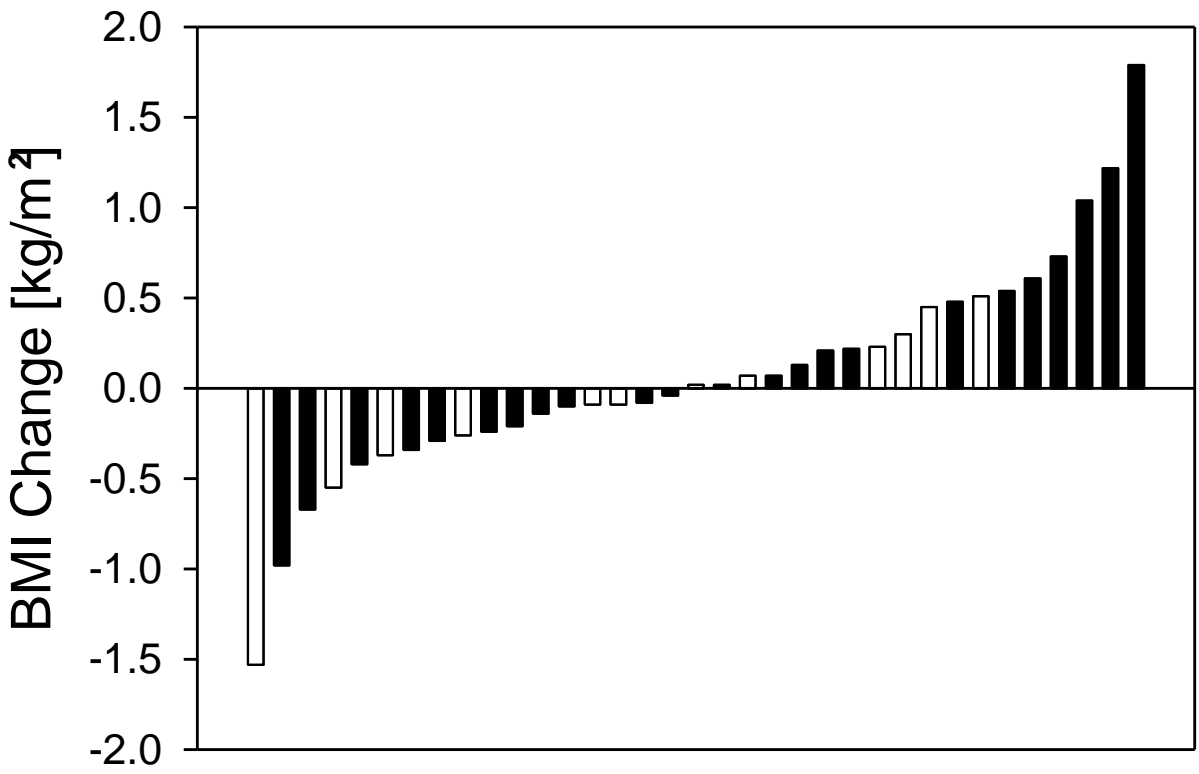


### Exercise

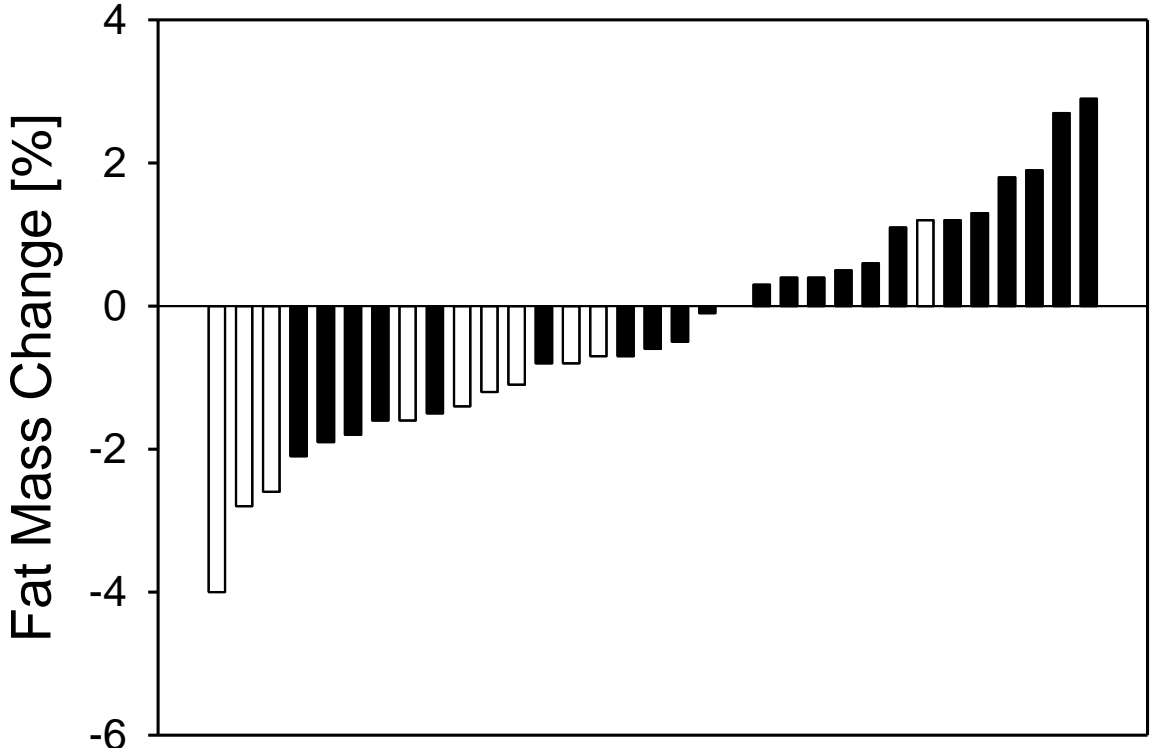


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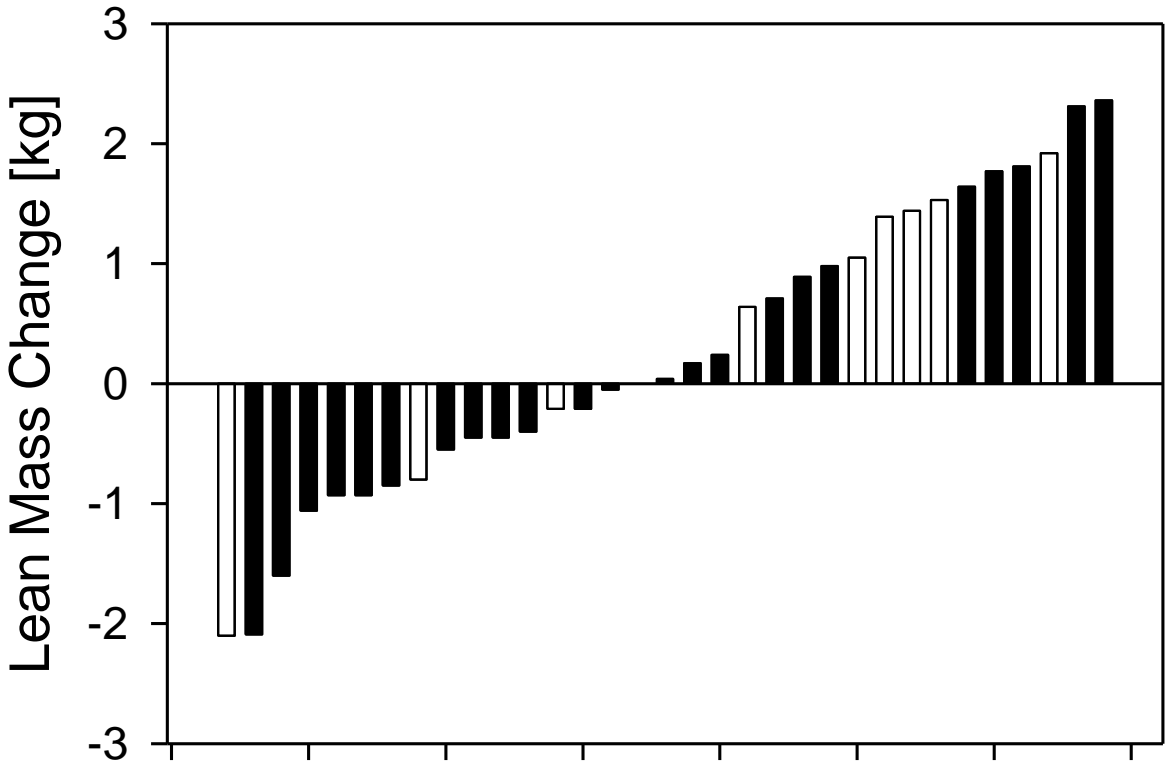
**A**



**B**



**C**



Participants: OV/OB  L