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# Physical exercise-related endophenotypes in Anorexia Nervosa

Laura Di Lodovico<sup>1\*</sup>, Hanna Hatteea<sup>1</sup>, Céline Couton<sup>2,3</sup>, Philibert Duriez<sup>1,4</sup>, Janet Treasure<sup>5</sup>  
and Philip Gorwood<sup>1,4</sup>

<sup>1</sup> Clinique des Maladies Mentales et de l'Encéphale, Hôpital Sainte-Anne, GHU Paris Psychiatrie et Neurosciences, F-75014 Paris, France

<sup>2</sup> Université Paris-Saclay, Psychiatrie-Comorbidités-Addictions, 94804 Villejuif, France.

<sup>3</sup> Psychiatry and addictology unit, APHP, Hôpitaux Universitaires Paris-Sud, Villejuif, France

<sup>4</sup> Université de Paris, Institute of Psychiatry and Neuroscience of Paris (IPNP), INSERM U1266, F-75014 Paris, France

<sup>5</sup> Section of Eating Disorders, Department of Psychological Medicine, Institute of Psychiatry, Psychology and Neuroscience, King's College London, London, United Kingdom

\*Corresponding Author

Laura Di Lodovico

Clinique des Maladies Mentales et de l'Encéphale

Hôpital Sainte-Anne, GHU Paris Psychiatrie et Neurosciences, F-75014 Paris, France

1 Rue Cabanis

Paris, 75014, France

Tel: (+33) 1 45 59 85 72

Fax: (+33) 1 45 65 89 43

E-mail: [laura.dilodovico@yahoo.com](mailto:laura.dilodovico@yahoo.com)

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35 The data that support the findings of this study are available from the corresponding author,  
36 upon reasonable request.

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### 39 **Statement of ethics**

40 The authors assert that all procedures contributing to this work comply with the ethical  
41 standards of the relevant national and institutional committees on human experimentation  
42 and with the Helsinki Declaration of 1975, as revised in 2008. This protocol was approved by  
43 the Île-de-France III Ethics Committee and the CNIL (Commission Nationale de  
44 l'Informatique et des Libertés). Written informed consent was obtained from each participant  
45 before inclusion.

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47 The authors have no conflicts of interest to declare.

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### 55 **Author contributions**

56 Laura Di Lodovico: original draft preparation, writing and editing, visualization, formal  
57 analysis, investigation, data curation.

58 Hanna Hatteea: conceptualization, methodology, investigation, data curation.

59 Céline Couton : investigation, data curation.

60 Philibert Duriez: investigation and supervision.

61 Janet Treasure: review and editing.

62 Philip Gorwood: conceptualization, methodology, project administration, supervision, formal  
63 analysis, resources, funding acquisition, review and editing.

64

65 **Abstract**

66 BACKGROUND

67 The persistence of physical exercise in Anorexia Nervosa (AN) despite underweight and  
68 its maintaining factors are poorly understood. The aim of this study was to explore the  
69 attitudes towards physical exercise and its effects on emotions, cognitive functioning and  
70 body image perception in patients with AN, and to search for exercise-related  
71 endophenotypes of the pathology.

72 METHODS

73 Physical exercise dependence, quantity and dysregulation were assessed by the  
74 Exercise Dependence Scale (EDS), the Godin Leisure Time Exercise Questionnaire  
75 (GLTEQ) and a standardized effort test in 88 patients with AN, 30 unaffected relatives  
76 and 89 healthy controls. Changes in positive and negative affect, cognitive rigidity, and  
77 body image distortion were measured before and after the effort test in the three groups.

78 RESULTS

79 Patients with AN had higher scores on the EDS and the GLTEQ and used more effort in  
80 the standardized effort test. These three measures of physical exercise correlated with  
81 negative emotions at baseline. After the effort test, patients with AN had marked  
82 emotional improvement, a moderate increase in body image distortion and a small  
83 increase in cognitive rigidity compared to HC. Unaffected relatives also had a significant  
84 post-exercise increase of positive emotion.

85 CONCLUSIONS

86 The mood-related drive for physical exercise has the characteristics of an  
87 endophenotype of the disorder. Excessive and driven physical exercise may be state-  
88 associated features of AN, driven by the positive effect on emotional wellbeing.

89 Keywords: Anorexia Nervosa, Physical Exercise, Endophenotype, Emotions, Body Image.

90

91 Anorexia Nervosa (AN) is characterized by persistent restriction of energy intake  
92 leading to significantly low body weight, a fear of becoming fat and a distortion of body  
93 image (American Psychiatric Association, 2013). Besides food restriction, starvation and  
94 purging behaviours, strategies to control weight and shape encompass an excessive and  
95 inappropriate practice of physical exercise (Dalle Grave, Calugi, & Marchesini, 2008;  
96 Meyer, Taranis, Goodwin, & Haycraft, 2011; Rizk et al., 2015).

97 A paradoxical increase in motor activity, in the context of the frailty associated  
98 with illness progression, has been found in up to 85% of patients with AN (Rizk et al.,  
99 2015; Sauchelli et al., 2015; Stiles-Shields, Bamford, Lock, & Le Grange, 2015). The  
100 unique character of this persistent drive to physical exercise leads to the hypothesis that  
101 driven (i.e. intense and compulsive) exercise constitutes an endophenotype of the  
102 disorder (Casper, 2016; Stiles-Shields et al., 2011). This hypothesis is further supported  
103 by the fact that the polygenic risk score (PRS) of anorexia nervosa significantly  
104 correlates ( $r=0.17$ ;  $p=10^{-4}$ ) with the PRS of physical activity (Watson et al., 2019).

105 The mechanism underpinning the maintenance of excessive physical exercise at  
106 advanced stages of AN is unknown. One hypothesis is that the mood regulating and  
107 anxiolytic properties of physical exercise may be involved (Dishman, 1985; Gümmer et  
108 al., 2015; Keyes et al., 2015). Other explanatory factors include enhanced cognitive  
109 rigidity (Di Lodovico & Gorwood, 2019) leading to highly stereotyped exercise routines,  
110 obsessive-compulsiveness (Halmi et al., 2005; Shroff et al., 2006) and an alteration of  
111 the reward system towards exercise and food restriction (Giel et al., 2013; O'Hara,  
112 Campbell, & Schmidt, 2015). These findings are integrated into the cognitive-behavioural  
113 model proposed by Meyer et al. (Meyer et al., 2011). In this model mood dysregulation,  
114 cognitive rigidity and distortion of body image are involved in a vicious circle whereby  
115 physical exercise is used as a strategy to cope with negative emotions and negative  
116 body perceptions.

117 The persistence of high motivation to exercise after weight restoration suggests  
118 that the tendency towards excessive physical exercise might be a state-independent,  
119 clinical feature of AN pathology (Klein et al., 2010; Shroff et al., 2006). The possible  
120 familial, endophenotype nature of this trait has not been studied. Endophenotypes are  
121 primarily state-independent, heritable subclinical traits associated with illness in the  
122 population, tending to co-segregate with illness within families and thus found in non-  
123 affected family members at higher rates than in the general population (Gottesman &  
124 Gould, 2003).

125 In the present study, the hypotheses tested were that patients with AN would  
126 show (1) higher levels of excessive and driven physical exercise compared with healthy  
127 controls, that (2) physical effort would increase positive emotions, and be associated with  
128 changes in cognitive rigidity and body image distortion (3), and that these effects have  
129 endophenotypic characteristics, i.e. are greater in unaffected relatives of patients with AN  
130 than in healthy controls.

## 131 **Materials and Methods**

### 132 **Participants**

133 The present study utilizes data collected as part of a monocentric open trial  
134 (NCT02995226). Consecutively admitted patients with AN, first-degree unaffected  
135 relatives (UR) and healthy controls (HC) were offered the opportunity to participate in this  
136 study. In total, 207 participants were included in three groups by parallel assignment: 1)  
137 AN (n=88, including 68 inpatients and 20 outpatients), 2) UR (n=30), all unrelated to the  
138 patients included, and 3) HC (n=89).

139 Inclusion criteria for the AN group were: female sex, age between 18 - 50 years,  
140 Body Mass Index (BMI) between 14 and 17.5 kg/m<sup>2</sup>, and diagnosis of AN according to  
141 the DSM-5 criteria (American Psychiatric Association, 2013). The Eating Disorder  
142 Inventory-2 and the MINI (Mini-International Neuropsychiatric Interview) 6.0.0 for DSM-IV  
143 (Sheehan et al., 1998) were performed by trained psychologists or psychiatrists.

144 Inclusion criteria for UR and HC were: female sex, age between 18 - 50 years,  
145 BMI > 17.5 kg/m<sup>2</sup>, and no personal history of eating disorder.

146 Exclusion criteria for all groups were: contraindications to the practice of an  
147 intensive sport, personal history of stroke, phlebitis, hypertension and/or heart attack,  
148 surgical, musculoskeletal, osteoarticular and/or neurological pathology, a first degree  
149 family history of stroke at the age of <45 years, a first degree familial history of heart  
150 attack and/or sudden death at the age of <55 years, and the existence of severe  
151 psychiatric diagnoses screened by the MINI (lifetime and/or current mood and/or  
152 psychotic disorders).

153 Personal history and/or a current diagnosis of eating disorders according to the  
154 MINI and/or the EDI-2 represented an exclusion criterion for the UR and HC groups.

155 All study procedures were approved by the Île-de-France III Ethics Committee and  
156 the *Commission Nationale de l'Informatique et des Libertés*. In accordance with the

157 Helsinki declaration, written informed consent was obtained from each participant before  
158 inclusion.

## 159 **Instruments**

160 Eating Disorder Inventory-2 (EDI-2). The EDI-2 (Cricquillon-Doublet, Divac, Gaillac,  
161 Dardennes, & Guelfi, 1995; Garner, 1991) explores attitudinal and behavioural  
162 dimensions relevant to eating disorders. Internal consistency is  $>.80$  in patients with AN  
163 for the eight EDI original scales (Garner, Olmstead, & Polivy, 1983),  $.65$  to  $.75$  for the  
164 three additional scales (Eberenz & Gleaves, 1994), and  $>.60$  in HC (Garner et al., 1983).

165 Exercise Dependence Scale-R (EDS-R). The EDS-R (Downs, Hausenblas, &  
166 Nigg, 2004) is a 21-item assessment of symptoms of exercise dependence based on the  
167 DSM-IV criteria for substance dependence. Higher scores indicate more symptoms of  
168 exercise dependence (Hausenblas & Downs, 2002). The French version of the EDS-R  
169 preserves the structural validity of the original scale and shows acceptable internal  
170 consistency, with Cronbach's alphas ranging from  $.75$  to  $.89$  (Kern, 2007).

171 Godin Leisure Time Exercise Questionnaire (GLTEQ). The GLTEQ (Godin &  
172 Shephard, 1997) allows a quantitative estimate of the average physical exercise  
173 practised over a 7-day period (Amireault & Godin, 2015). To ensure the interpretability of  
174 the GLTEQ for inpatients with AN, the latter were asked to rate the amount of physical  
175 exercise performed during the week preceding the admission at the unit.

176 Standardized effort test. A standardized effort test was performed by each  
177 participant on a bicycle connected to a computer by a TACX hometrainer® software. The  
178 standardized effort test is designed to obtain the same load of effort from each  
179 participant. During the standardized effort test, heart rate, power (watts), and speed  
180 (km/h) were recorded every 30 seconds. There were three phases in this test (Figure 1).  
181 In the "spontaneous effort" phase, participants were asked to ride for 1 kilometre at the  
182 speed they would subjectively feel as "pleasurable". Next, in the "maximum effort phase",  
183 the power of the device automatically rose 30 watts every 2 minutes until the workload  
184 became unbearable: the power of the last segment completed corresponded to the  
185 maximum aerobic power (MAP). The "imposed effort phase" was a 15-minute ride at  
186 50% of the MAP reached in the second phase. The "effort dysregulation index" was  
187 calculated as the percentage of MAP delivered during the "spontaneous effort" phase  
188 (figure 1). The higher this percentage, the smaller the subjective difference between  
189 "pleasurable" and "maximum" effort, i.e. pleasure linked to physical effort. Baseline  
190 glycaemia and time after the last meal were also recorded as potential confounding  
191 factors (Kennedy & Scholey, 2000).

192 Wisconsin Card Sorting Test (WCST). The WCST (Heaton, Chelune, Talley, Kay,  
193 & Curtiss, 1993) entails matching presented cards with one of four multidimensional  
194 category cards according to implicit, changing rules (Tchanturia et al., 2012). The proxy  
195 measure of cognitive rigidity was the percentage of perseverative errors. In order to limit  
196 the learning effect the 64-item-version (Kongs, Thompson, Iverson, & Heaton, 2000) was  
197 split in half to measure performance before and after the effort test.

198 Body image distortion assessment. Patients were invited to choose the silhouette  
199 that most closely represented their perceived body image among ten female silhouettes,  
200 each corresponding to a specific BMI (Mouchès, 1992). Body image distortion was  
201 calculated as the difference between the BMI of the silhouette chosen and real BMI (Sala  
202 et al., 2012). The order of the images was randomised before and after the exercise to  
203 avoid a practice effect.

204 Positive and Negative Affect Schedule (PANAS). The 10-item version of the  
205 PANAS validated in French (Gaudreau, Sanchez, & Blondin, 2006) assesses momentary  
206 positive and negative affect on a 5-point Likert scale from “not at all” to “extremely”. The  
207 two scales show a good internal consistency with a Cronbach’s alpha  $>.90$  for positive  
208 scale and  $>.80$  for negative items (Gaudreau et al., 2006). The correlation between the  
209 two scales is invariably low ( $-.15$ ) (Watson, Clark, & Tellegen, 1988).

## 210 **Statistical analysis**

211 All data were preliminarily assessed for parametric distribution by the Kolmogorov-  
212 Smirnov test.

213 Student tests for independent samples were employed for inter-group comparisons,  
214 in order to assess differences between patients with AN and HC and between HC and  
215 UR in the three measures of physical exercise and in the effects on the variables  
216 assessed before and after the standardized effort test. To fulfil the criteria for an  
217 endophenotype, a variable should be associated with target illness, and be more  
218 common in UR than in HC (Gottesman & Gould, 2003) with an effect size of at least 50%  
219 of that of the difference between AN and HC (Iacono, Malone, & Vrieze, 2017).

220 Bivariate correlation analyses were employed separately in the AN, HC and UR  
221 groups to assess the relationships between physical exercise measures and emotional  
222 state (PANAS), body image distortion and perseverative errors as an index of rigidity  
223 (WCST).

224 An analysis of covariance (ANCOVA) was run to rule out the influence of potentially  
225 confounding, uncontrolled variables on the differences found in the variables of interest



226 between UR and HC, in order to confirm their endophenotypic nature.

227 All tests were performed using SPSS (IBM Corp. Released 2012. IBM SPSS  
228 Statistics for Macintosh, Version 21.0. Armonk, NY: IBM Corp).

## 229 **Results**

### 230 **Group characteristics**

231 Patients with AN were similar in age to HC. UR were older since mothers were  
232 included. AN and UR groups had higher body image distortion and lower positive  
233 emotions than HC at baseline (table 1).

### 234 **Characteristics of physical exercise**

235 Patients with AN had higher amounts of weekly exercise, exercise dependence  
236 and effort dysregulation indexes than HC. Effect sizes by Cohen's *d* are shown in table 1.  
237 The amounts of weekly exercise in AN inpatients (prior to admission) and outpatients  
238 were comparable ( $51.53 \pm 31.41$  vs  $54.90 \pm 28.62$  METs,  $t=.43$ ;  $df=86$ ;  $p=.67$ ;  $d=.11$ ).

239 UR had lower exercise levels and dependence, but higher, non-significant ( $d=.13$ )  
240 effort dysregulation indexes than HC (table 1).

### 241 **The relationship between physical exercise and emotions, cognitive rigidity** 242 **and body image distortion**

243 In patients with AN, following the experimental effort test, there was a large  
244 increase of positive emotions, moderate increases of body image distortion and  
245 decreases of negative emotions, and small increase of cognitive rigidity, when compared  
246 to HC. See table 1 for effect sizes. Post-exercise increases of positive emotion and body  
247 image distortion were uncorrelated ( $r=.15$ ;  $p=.18$ ).

248 In UR, following the effort test, there was a significant increase of positive  
249 emotions compared to HC, with an effect size larger than 50% of that of the difference  
250 between AN and HC (table 1). This remained higher after controlling for age and time  
251 from last meal ( $F(1,117)=6.89$ ;  $p=.01$ ).

252 In patients with AN, negative emotions at baseline were significantly correlated  
253 with the three measures of physical exercise, and these correlations did not lose  
254 statistical significance when the analyses were repeated after excluding the 10 patients  
255 diagnosed with depression ( $r=.27$ ;  $p=.02$  for the EDS,  $r=.31$ ;  $p<.01$  for the GLTEQ and  
256  $r=.23$ ;  $p=.04$  for the effort dysregulation index). Body image distortion was positively  
257 correlated with the amount of exercise practiced (all correlations are reported in table 2).

258 In UR, only a positive correlation between body image distortion and the EDS  
259 score was found.

## 260 Discussion

261 This study explored the nature of physical exercise in AN, and its relationship with  
262 positive and negative emotions, cognitive rigidity and body image distortion. We also  
263 explored the familial nature of this relationship to examine for potential endophenotypes.

264 A tendency to excessive and driven exercise significantly distinguished patients  
265 with AN from HC. A strong relationship was found between negative emotions and a  
266 more intensive frequency, dependence and dysregulation of physical exercise in AN,  
267 suggesting a possible “anti-depressive” drive of physical exercise. This finding was  
268 further confirmed by a significant increase of positive emotions after a single bout of  
269 exercise in patients but also in UR, fulfilling the criteria of an endophenotype (Gottesman  
270 & Gould, 2003). Body image distortion was increased after exercise in patients with AN  
271 only, supporting a state-related relationship between body image distortion and physical  
272 exercise in AN.

273 The finding of more pronounced amounts and drive for physical exercise in AN is in  
274 line with the literature. High amounts of exercise (Bratland-Sanda et al., 2009), higher  
275 levels of exercise dependence (Di Lodovico & Gorwood, 2019), and a stronger  
276 willingness to work for the opportunity to exercise (Klein et al., 2010) could be explained  
277 by a tendency for AN patients to perceive exercise-related stimuli as more rewarding and  
278 pleasant (Giel et al., 2013; Kullmann et al., 2014).

279 In previous research, negative affect regulation was presented as the main reason for  
280 exercise in patients with AN (Bratland-Sanda et al., 2009), higher levels of negative  
281 emotions were described in patients who exercise excessively (Shroff et al., 2006), and  
282 physical exercise abuse was identified as a predictor of emotional instability in AN (Selby  
283 et al., 2015). Our results demonstrate that the positive emotional consequence of  
284 physical exercise in AN has the features of an endophenotype. This positive  
285 reinforcement (Klein et al., 2010; Walsh, 2013) may lead to the addictive properties of  
286 physical exercise in AN (Karr et al., 2017; Klein et al., 2004).

287 Although positive emotion improved after exercise, body image perception worsened,  
288 probably because of abnormal interoception in AN (Jacquemot & Park, 2020). Taken  
289 together, the two divergent perceptions of feeling better because of positive emotions  
290 and having greater body image distortion might explain the vicious circle that maintains  
291 the drive for exercise in patients with AN (Dalle Grave et al., 2008; Hagman et al., 2015).

292 Several limitations are present in this study. The drive to exercise was not compared  
293 in patients with restricting type vs bingeing-purging type, nor in inpatients vs outpatients.  
294 Nevertheless, previous studies found comparable attitudes towards exercise between  
295 these subgroups (Di Lodovico & Gorwood, 2019; Keyes et al., 2015). This research lacks  
296 an assessment of anxious and depressive symptomatology, as subclinical depressive  
297 elements could have influenced the PANAS at baseline. Nevertheless, this chance was  
298 limited by screening mood disorders and repeating the analyses after excluding the ten  
299 patients diagnosed with depression. Potential confounders such as the smaller size and  
300 older age of the UR group may have influenced some exercise-related findings. To  
301 address this limitation, we controlled those that were statistically different between  
302 groups (such as age and time from last meal) in an analysis of covariance, and we  
303 analysed all physical efforts parameters according to each participant baseline MAP,  
304 therefore controlling for its variability.

305 The main strengths of this study are the use of an experimental approach, testing a  
306 direct effect of physical exercise on the main factors involved in its onset and  
307 maintenance, and the assessment of these same effects in UR, exploring for the first  
308 time exercise-related endophenotypes in AN.

## 309 **Conclusion**

310 The mood-enhancing effect of physical exercise could represent an endophenotype  
311 of AN, suggesting how and why exercise becomes a dominant form of mood regulation.  
312 However, the increased body image distortion following exercise may allow this  
313 behaviour to become compulsive. Alternative mood-regulating strategies may be needed  
314 to break this vicious circle.

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## Figure Legends

Fig. 1. Design of the study testing positive and negative emotions, cognitive flexibility and body image distortion in patients with anorexia nervosa (AN), healthy controls (HC) and unaffected relatives (UR), at baseline (before exercise) and after a bout of physical exercise (after physical effort).

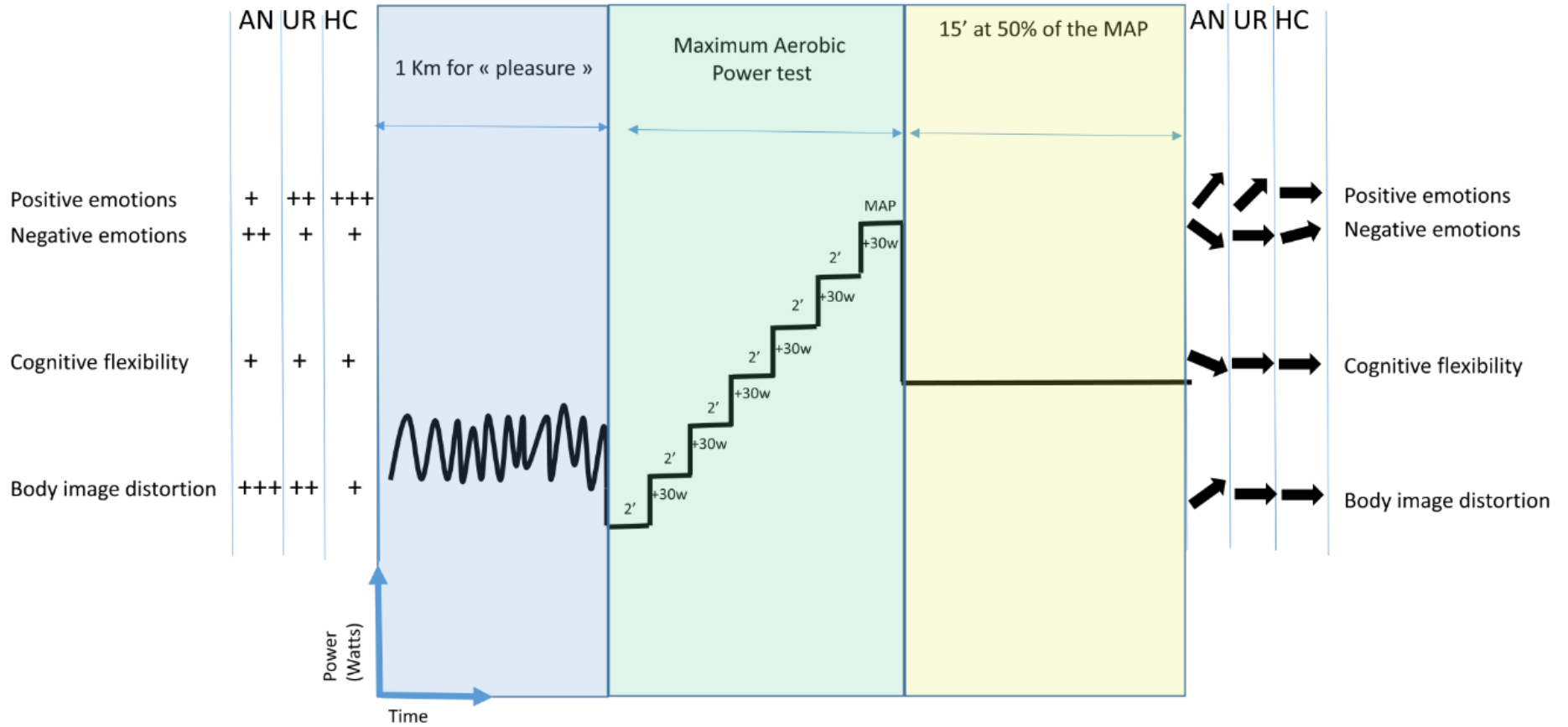
## Table Legends

Table 1. Inter-group comparison at baseline, during and after a standardized effort test, of 88 patients with anorexia nervosa (AN), 30 unaffected relatives (UR) and 89 healthy controls (HC).

Table 2. Bivariate correlations between physical exercise measures and emotional status, body image perception and cognitive rigidity in a group of 88 patients with Anorexia Nervosa (AN), 30 Unaffected Relatives (UR) and 89 Healthy Controls (HC). Correlations were calculated separately for each group. Asterisks indicate statistically significant correlations.

Figure 1

Before physical effort → ← Standardized physical effort → → After physical effort



AN: Anorexia Nervosa, UR: Unaffected first-degree Relatives, HC: Healthy Controls

Table 1: Inter-group comparison at baseline, during and after a standardized effort test, of 88 patients with anorexia nervosa (AN), 30 unaffected relatives (UR) and 89 healthy controls (HC).

	AN (n=88)	UR (n=30)	HC (n=89)	AN vs UR				AN vs HC				HC vs UR			
				t	DF	p	Cohen's d	t	DF	p	Cohen's d	t	DF	p	Cohen's d
<b>Baseline characteristics and performances</b>															
Age (years)	26.83 ± 7.57	34.53 ± 11.85	27.46 ± 5.93	-3.33	116	<.01	0.87	.62	175	.54	0.09	-3.13	117	<.01	0.90
BMI (kg/m <sup>2</sup> )	16.17 ± .99	21.64 ± 2.10	21.82 ± 2.34	-13.75	116	<.01	4.03	15.72	175	<.01	2.35	.34	117	.73	0.06
Baseline glycaemia (g/l)	.98 ± .21	.96 ± .10	.95 ± .15	.44	116	.66	0.07	.87	173	.39	0.13	-.48	116	.62	0.09
Time from last meal (min)	259.39 ± 838.49	122.83 ± 6.39	167.43 ± 164.69	1.52	115	.13	0.19	1.00	174	.32	0.15	2.55	117	.01	0.31
EDI-2 total score	91.07 ± 48.00	21.60 ± 16.98	25.54 ± 20.46	<b>11.56</b>	<b>115</b>	<.01	1.64	<b>11.73</b>	<b>174</b>	<.01	1.78	1.04	117	.30	0.20
EDS score	61.16 ± 27.48	31.73 ± 8.19	39.52 ± 18.45	<b>8.95</b>	<b>116</b>	<.01	0.45	<b>6.37</b>	<b>175</b>	<.01	0.96	<b>2.23</b>	<b>118</b>	<b>.03</b>	0.45
GLTEQ total score	52.30 ± 30.67	28.57 ± 18.63	44.93 ± 24.00	<b>5.04</b>	<b>116</b>	<.01	0.72	<b>1.78</b>	<b>175</b>	<b>.04</b>	0.27	<b>3.85</b>	<b>117</b>	<.01	0.72
Baseline PANAS for positive emotions	10.80 ± 3.21	13.00 ± 2.96	14.92 ± 3.19	<b>-3.45</b>	<b>116</b>	<.01	0.70	<b>8.57</b>	<b>175</b>	<.01	1.29	<b>3.01</b>	<b>117</b>	<.01	0.61
Baseline PANAS for negative emotions	13.63 ± 4.52	8.83 ± 2.48	8.24 ± 2.43	<b>7.25</b>	<b>116</b>	<.01	1.17	<b>9.86</b>	<b>175</b>	<.01	1.49	-1.15	117	.25	0.24
Baseline WCST number of perseverative errors	3.13 ± 2.51	3.07 ± 4.26	2.78 ± 2.39	.08	96	.93	0.02	.82	131	.41	0.38	.34	93	.73	0.09
Baseline body image distortion (kg/m <sup>2</sup> )	5.08 ± 3.23	2.35 ± 2.32	1.07 ± 2.93	<b>5.00</b>	<b>116</b>	<.01	0.90	<b>8.66</b>	<b>175</b>	<.01	1.30	<b>-2.45</b>	<b>117</b>	<b>.02</b>	0.46
<b>Standardized effort test</b>															
Maximum aerobic power (MAP)	112.27 ± 34.99	139.00 ± 29.64	151.00 ± 32.94	<b>-4.07</b>	<b>116</b>	<.01	0.79	<b>8.30</b>	<b>175</b>	<.01	1.24	1.48	117	.14	0.56
Spontaneous effort average power	38.49 ± 17.96	40.80 ± 13.17	44.15 ± 17.41	.75	116	.45	0.14	2.13	175	.03	0.32	1.10	117	.27	0.20
Effort dysregulation index (average spontaneous power/MAP)	35.08 ± 15.38%	30.15 ± 10.22%	28.52 ± 13.05%	<b>1.98</b>	<b>116</b>	.05	0.34	<b>3.05</b>	<b>175</b>	<.01	0.46	.70	117	.24	0.13
<b>Changes induced by physical effort</b>															
PANAS positive emotions after-before effort	2.69 ± 3.52	1.97 ± 2.52	.52 ± 2.65	1.22	116	.22	0.55	<b>4.65</b>	<b>175</b>	<.01	0.70	<b>2.69</b>	<b>117</b>	<.01	0.55
PANAS negative emotions after-before effort	-.12 ± 2.88	.20 ± 2.04	.85 ± 2.12	.67	116	.50	0.31	2.57	175	.01	0.39	1.50	117	.14	0.31
WCST number of perseverative errors after - before effort	.22 ± 3.36	-.60 ± 4.10	-0.95 ± 2.37	.96	96	.34	0.12	<b>2.33</b>	<b>130</b>	<b>.02</b>	0.40	.44	93	.66	0.12
Perceived body image after - before effort (kg/m <sup>2</sup> )	.50 ± 1.54	-.01 ± 1.22	.12 ± 1.51	1.82	116	.07	0.09	<b>1.66</b>	<b>174</b>	<b>.04</b>	0.25	.45	117	.65	0.09

AN= Anorexia Nervosa; UR= Unaffected Relatives; HC= Healthy Controls; BMI= Body Mass Index; EDI-2= Eating Disorder Inventory-2; EDS= Exercise Dependence Scale; GLTEQ= Godin Leisure Time Exercise Questionnaire; PANAS= Positive And Negative Affect Schedule; WCST= Wisconsin Card Sorting Test.

Table 2: Bivariate correlations between physical exercise measures and emotional status, body image perception and cognitive rigidity in a group of 88 patients with Anorexia Nervosa (AN), 30 Unaffected Relatives (UR) and 89 Healthy Controls (HC). Correlations were calculated separately for each group. Asterisks indicate statistically significant correlations.

Exercise measures	n	PANAS baseline positive emotions		PANAS baseline negative emotions		WCST perseverative errors at baseline		Body image distortion at baseline	
		r	p	r	p	r	p	r	p
<b>EDS score</b>									
AN	88	-.15	.15	.27*	.01	.02	.86	.08	.88
UR	30	-.20	.28	-.01	.95	-.10	.58	.04*	.03
HC	89	.29*	<.01	-.04	.74	-.04	.78	.07	.52
<b>GLTEQ score</b>									
AN	88	-.20	.06	.30*	<.01	-.09	.86	.29*	<.01
UR	30	.11	.56	-.07	.71	-.27	.15	-.25	.19
HC	89	.27*	.01	.02	.83	.02	.84	.15	.17
<b>Effort dysregulation index</b>									
AN	88	-.12	.25	.23*	.03	.02	.85	.06	.56
UR	30	-.09	.63	.09	.64	.29	.12	.31	.09
HC	89	-.05	.63	-.05	.62	.05	.67	<.01	.98

AN= Anorexia Nervosa; UR= Unaffected Relatives; HC= Healthy Controls; PANAS= Positive and Negative Affect Schedule; WCST= Wisconsin Card Sorting Test; EDS= Exercise Dependence Scale; GLTEQ= Godin Leisure Time Exercise Questionnaire.