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Changes in Cardiorespiratory Fitness After Gastric Bypass: Relations with Accelerometry-Assessed Physical Activity

Alice Bellicha, Cécile Ciangura, Céline Roda, Adriana Torcivia, Pierre Portero,
Jean-Michel Oppert

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11 **Authors names and affiliations:**

12 Alice BELLICHA, PhD^{1,2}, Cécile CIANGURA, MD^{2,3}, Céline RODA, PhD^{3,4}, Adriana

13 TORCIVIA, MD⁵, Pierre PORTERO, PhD¹, Jean-Michel OPPERT, MD , PhD^{2,3}

14 1- Laboratory Bioengineering, Tissues and Neuroplasticity – EA7377, University Paris-Est

15 Créteil; 8 rue du Général Sarrail 94000 Créteil, France

16 2- Institute of Cardiometabolism and Nutrition; Sorbonne University, Faculty of Medicine;

17 47-83 boulevard de l'hôpital 75013 Paris, France

18 3- Assistance Publique-Hôpitaux de Paris, Pitié-Salpêtrière Hospital, Department of

19 Nutrition, Sorbonne University, Faculty of Medicine; 47-83 boulevard de l'hôpital 75013

20 Paris, France

21 4- INSERM, UMR 1153 – CRESS, HERA (Health Environmental Risk Assessment) team,

22 Paris Descartes University, Paris Faculty of Pharmacy; 4 avenue de l'Observatoire 75006

23 Paris, France

24 5- Assistance Publique-Hôpitaux de Paris, Pitié-Salpêtrière Hospital, Department of

25 Digestive and Hepato-Pancreato-Biliary Surgery, Sorbonne University, Faculty of Medicine;

26 47-83 boulevard de l'hôpital 75013 Paris, France

27

28 **e-mail addresses:**

29 Alice Bellicha: alice.bellicha@u-pec.fr

30 Cécile Ciangura: cecile.ciangura@aphp.fr

31 Céline Roda: celina.roda@parisdscartes.fr
32 Adriana Torcivia: adriana.torcivia@aphp.fr
33 Pierre Portero: pierre.portero@u-pec.fr
34 Jean-Michel Oppert: jean-michel.oppert@aphp.fr

35

36 **Correspondance to:**

37 Prof. Jean-Michel Oppert, MD, PhD
38 e-mail: jean-michel.oppert@aphp.fr
39 Tel: +33 1 42 17 57 79. Fax: + 33 1 42 17 59 63
40 Department of Nutrition –Pitié-Salpêtrière University Hospital
41 47-83 Boulevard de l’Hôpital
42 75013 Paris, France

43

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54 **Title:** Changes in cardiorespiratory fitness after gastric bypass: relations with accelerometry-
55 assessed physical activity

56

57 **Abstract**

58 **Background:** Exercise training optimizes cardiorespiratory fitness (CRF) after bariatric
59 surgery but the effect of spontaneous physical activity is not well known. This study aimed to
60 objectively quantify changes in CRF and habitual physical activity 6 months after bariatric
61 surgery and to examine whether change in CRF was related to change in physical activity.

62 **Methods:** Secondary analyses were performed on data from women who underwent Roux-
63 en-Y gastric bypass (RYGB) between 2010 and 2014. Measurements were performed before
64 and 6 months after RYGB and included $\dot{V}O_2$ peak (graded maximal exercise test on a cycle
65 ergometer), habitual physical activity (Actigraph GT3x accelerometer worn during 7 days),
66 and body composition (DXA absorptiometry). Changes after RYGB were analyzed using
67 Wilcoxon signed-rank test. Relations between change in CRF and change in physical activity
68 were analyzed with Spearman correlations adjusted on age and preoperative BMI.

69 **Results:** Forty-five women (median [P₂₅-P₇₅] age: 43.0 [38.0-51.0] y, BMI: 42.6 [40.0-45.5]
70 kg/m²) were included. Mean (SD) weight loss 6 months after RYGB was -27.5 (7.9) kg
71 (P<0.001). Absolute $\dot{V}O_2$ peak decreased by 0.35 (0.50) L/min (P<0.001) and relative
72 $\dot{V}O_2$ peak tended to increase by 1.7 (5.3) mL/kg/min (P=0.06), both with large inter-
73 individual variability. Based on objective accelerometry data, daily steps and moderate-to-
74 vigorous physical activity increased by 1,275 (3,164) steps/d and 7.6 (19.3) min/d,
75 respectively (both P<0.05). Change in absolute $\dot{V}O_2$ peak was positively related to change in
76 moderate-to-vigorous physical activity (r=0.35, P=0.03).

77 **Conclusions:** The decrease in absolute CRF observed 6 months after RYGB might be
78 prevented by increasing habitual physical activity.

79 **Trial Registration:** clinicaltrials.gov Identifier: NCT01113996

80

81 **Key words**

82 Physical fitness, $\dot{V}O_2$ max, physical activity patterns, accelerometry, gastric bypass, obesity

83

84 **Introduction**

85

86 Bariatric surgery induces marked weight loss, reduces mortality and improves obesity-related
87 comorbidities as well as health-related quality of life [1, 2]. Current guidelines for clinical
88 care in this setting include promotion of physical activity (PA) to maintain or improve overall
89 health and physical fitness [1]. Physical fitness is a major health indicator [3]. The concept of
90 physical fitness includes different dimensions such as cardiorespiratory fitness (CRF),
91 muscular fitness, and flexibility [4]. The gold-standard method for measuring CRF is to
92 perform a graded maximal exercise test with direct measurement of maximal oxygen
93 consumption ($\dot{V}O_2\text{max}$) [5], expressed either in absolute values (L/min) or relative to body
94 weight (mL/kg/min). Estimates of CRF can also be calculated from heart rate response or
95 exercise time to exhaustion during maximal or submaximal exercise tests [5]. Low CRF is
96 recognized as a major risk factor for all-cause mortality and cardiovascular events, including
97 in patients with obesity [6, 7]. CRF is also a marker of functional capacity and ability to
98 perform adequately the tasks of daily living [3]. In the bariatric surgery setting, low CRF has
99 been associated with increased short-term post-operative complications [8].

100

101 Patients seeking bariatric surgery are characterized by poor physical fitness as measured by
102 low CRF, with mean $\dot{V}O_2\text{max}$ values below 20 mL/kg/min [9]. Surgery-induced weight loss
103 has been associated with a significant, although modest, increase in relative $\dot{V}O_2\text{max}$ [9-13].
104 In contrast, absolute $\dot{V}O_2\text{max}$ (L/min) has been found either decreased [9, 10, 14] or
105 unchanged [12] after bariatric surgery. However, published studies have not consistently
106 reported changes in both absolute and relative $\dot{V}O_2\text{max}$. Therefore, there is a need to better
107 assess the magnitude of change in both absolute and relative CRF values after bariatric
108 surgery.

109

110 PA is the main modifiable determinant of CRF but the response to PA varies greatly between
111 individuals and also depends on genetic factors [15]. We showed in a recent systematic
112 review and meta-analysis that endurance-based exercise training programs performed after
113 bariatric surgery help improving CRF [16, 17]. Little is known about the role of habitual (i.e.
114 spontaneous) PA in this setting. Change in self-reported PA has been found associated with
115 change in calculated $\dot{V}O_2\text{max}$ estimates [18]. However, association between objectively-
116 measured PA and directly measured $\dot{V}O_2\text{max}$ has not been investigated.

117

118 Therefore, the aims of this analysis were to quantify changes in CRF ($\dot{V}O_2\text{peak}$ expressed as
119 absolute value or relative to body mass) and in accelerometry-assessed PA patterns 6 months
120 after RYGB and to examine whether change in CRF was related to change in habitual PA,
121 with special attention to moderate-to-vigorous PA which forms the basis of current PA
122 recommendations.

123

124 **Methods**

125

126 **Study population**

127 This analysis was conducted on a subgroup of participants from a randomized clinical trial
128 examining the effect of exercise on physical fitness and body composition 6 months after
129 RYGB (clinicaltrials.gov Identifier: NCT01113996) [19]. In that trial performed at a single
130 academic center, patients undergoing RYGB and recruited from 2010 to 2014 were randomly
131 assigned to usual care (controls, N=22), or usual care and additional oral protein intake
132 (N=31), or usual care, additional protein intake and supervised resistance training (N=23). All
133 patients were encouraged to accumulate 150 min/wk of moderate-intensity PA, as part of

134 usual care [20]. As reported elsewhere, analyses revealed no differences in changes in CRF
135 and habitual PA between the three groups [19]. Therefore, data from patients included in the
136 control group and protein group were pooled for analyses in the present study. The study
137 protocol was approved by the ethics committee of our institution. All patients signed a
138 written informed consent prior to initiating the study.

139

140 **Measures**

141

142 All measurements were performed before and 6 months after RYGB [19]. CRF was measured
143 by indirect calorimetry (Cardiac Assessment System for Exercise, CASE, GE Medical
144 Systems Information Technologies Inc.) during a graded maximal exercise test on a cycle
145 ergometer (GE Healthcare), as previously described [19]. Maximally achieved oxygen
146 consumption ($\dot{V}O_{2peak}$) was determined as the highest attained $\dot{V}O_2$ during the test and
147 expressed in absolute values (L/min) and relative to body mass (mL/kg/min) and to lean body
148 mass (mL/kg LBM/min).

149

150 Habitual PA and sedentary time were measured using the Actigraph GT3x accelerometer
151 (Manufacturing Technology, Inc., FL, USA). Participants were asked to wear the Actigraph
152 at the hip using the provided elastic belt for seven consecutive days during all waking hours
153 except during water-based activities. Data were considered valid when the accelerometer was
154 worn for at least 4 days during at least 8 h each day [21]. Analyses were restricted to patients
155 who provided valid accelerometry data both before and 6 months after RYGB. Based on
156 previous literature [22], cut-points below 100 counts/min, between 100 and 1,951 counts/min,
157 between 1,952 and 5,723 counts/min and over 5,724 counts/min were used to quantify
158 sedentary behavior, light, moderate and vigorous intensity PA, respectively. Moderate-to-

159 vigorous PA (MVPA) bouts were defined as 10 or more consecutive min above the MVPA
160 activity counts threshold with allowance of 2 min below this threshold [23]. Daily steps,
161 corresponding to the total steps accumulated during wear time for a day, were calculated. As
162 previously described, a conservative approach was used to determine step counts: only steps
163 taken at an intensity ≥ 500 counts/min were registered [24]. Patients were considered
164 compliant to the 2008 US PA guidelines when MVPA accumulated in ≥ 10 -min bouts was
165 ≥ 150 min/wk [4] and compliant to the 2018 US PA guidelines when total MVPA was ≥ 150
166 min/wk [25].

167

168 Body composition (fat mass, lean body mass) was measured by DXA scanning (Hologic
169 Discovery W, software v12.9; Hologic, Bedford, MA), as previously described [19]. Weight
170 loss was expressed change in body weight and in body mass index (BMI). Diabetes was
171 defined according to a fasting blood glucose >7 or >11 mM two hours after a 75-g oral
172 glucose tolerance test, or the use of antidiabetic drugs, insulin or GLP-1 analogues [19].

173

174 **Statistical analyses**

175 Pre- and post-operative values are presented as median values (25th-75th percentile) for
176 continuous data and frequencies and percentages for categorical data. Pre- to post-operative
177 changes are presented as mean (SD). Mean (min-max) values are presented to characterize
178 interindividual variability in CRF and MVPA changes. Given the non-normality of most
179 variables, non-parametric tests were used. Preoperative and post-operative values were
180 compared with Wilcoxon signed-rank test for continuous variables and with McNemar test
181 for categorical variables (proportion of participants with obesity comorbidities or compliant
182 with PA recommendations). Relations between change in CRF and change in MVPA were

183 analyzed with Spearman correlations adjusted for age and preoperative BMI. The null
184 hypothesis was rejected at $P < 0.05$. Analyses were performed using R version 3.4.3.

185

186 **Results**

187

188 **Participant characteristics**

189 From the 53 participants included in the initial trial in the groups without PA intervention, 45
190 participants provided valid accelerometry data before and after surgery and 41 participants
191 also performed a maximal exercise test at both time points. Participants who did not provide
192 valid accelerometry and $\dot{V}O_2$ peak data (N=12) did not differ significantly from participants
193 who provided valid data (data not shown). Before surgery, 11 (24.4%) patients had type 2
194 diabetes. Six months after RYGB, a significant weight loss (mean [SD]) -27.5 [7.5] kg, fat
195 mass and lean body mass loss (all $P < 0.001$) was observed (Table 1). The proportion of
196 participants with type 2 diabetes and hypertension tended to decrease ($P = 0.07$ and $P = 0.08$,
197 respectively).

198

199 **Changes in CRF and in accelerometry-assessed physical activity**

200 Absolute $\dot{V}O_2$ peak significantly decreased after RYGB by -0.35 (0.50) L/min ($P < 0.001$)
201 (Table 1), with values ranging from -1.30 to +0.53 L/min. $\dot{V}O_2$ peak relative to body weight
202 tended to increase by 1.7 (5.3) mL/kg/min ($P = 0.06$), with values ranging from -9.6 to +10.8
203 mL/kg/min. $\dot{V}O_2$ peak relative to lean body mass was not significantly different 6 months
204 after RYGB.

205 Accelerometer wear time did not differ 6 months after RYGB. A significant increase in daily
206 steps (all $P < 0.05$) was observed. Mean duration of moderate- and vigorous-intensity PA
207 significantly increased ($P < 0.05$), which resulted in a +39.7 (84.5) % increase in total MVPA

208 (P<0.05). Change in total MVPA ranged from -23 to +69 min/d. The duration of MVPA
209 accumulated in ≥ 10 -min bouts increased on average by more than two-fold (P<0.05). The
210 proportion of MVPA accumulated in ≥ 10 -min bouts also increased from 7% to 16% of total
211 MVPA (P<0.05). The number (%) of patients who did not engage in any MVPA bout ≥ 10
212 min changed from 16 (36%) before RYGB to 8 (18%) after RYGB (P=0.08). However, the
213 proportion of patients compliant to the 2008 and the 2018 US PA guidelines was not
214 significantly different 6 months after RYGB (9 to 20%, P = 0.07 and 60 to 67%, P=0.60,
215 respectively). The duration of sedentary time and light-intensity PA was not different after
216 RYGB.

217

218 **Relations between changes in CRF and MVPA**

219 When adjusting for age and preoperative BMI, change in absolute $\dot{V}O_{2peak}$ after RYGB was
220 positively related to change in total MVPA (r=0.35, P=0.03) (Figure 1a). Change in relative
221 $\dot{V}O_{2peak}$ tended to be related to change in total MVPA (r=0.30, P=0.07) (Figure 1b).

222

223 **Discussion**

224

225 In this study, we assessed changes in CRF and in accelerometry-assessed habitual PA after
226 bariatric surgery in women with obesity. Six months after RYGB, we observed a significant
227 decrease in absolute $\dot{V}O_{2peak}$ and a significant increase in habitual PA, with large inter-
228 individual variability for both outcomes. We also found that change in CRF was positively
229 related to change in MVPA.

230

231 Our findings strengthen the notion that absolute CRF decreases in the first months after
232 bariatric surgery [9, 10, 14]. In contrast, because of massive weight loss, relative $\dot{V}O_{2peak}$

233 increases after bariatric surgery [9-13]. Relative $\dot{V}O_2$ peak being a strong predictor of both
234 mortality and functional impairment, this is an important benefit of bariatric surgery.
235 Previous studies had reported mean increases in $\dot{V}O_2$ peak 6 months after bariatric surgery
236 ranging from +1.3 mL/kg/min [11] to 5.2 mL/kg/min [10]. The +1.7 mL/kg/min increase in
237 $\dot{V}O_2$ peak observed in our study is therefore consistent with previous results. However,
238 despite such increase, mean $\dot{V}O_2$ peak remains very low after surgery, with mean values
239 around 20 to 25 mL/kg/min, corresponding to that usually observed in older women from the
240 general population [26]. Further improving CRF in this context is therefore an important
241 objective to optimize the benefits of bariatric surgery on health status and functional capacity.

242

243 Our data suggest that increasing habitual MVPA may be an important contributor to
244 maintaining CRF in the first months after bariatric surgery. This in line with controlled trials
245 that reported improvements in CRF after an exercise training program in patients undergoing
246 bariatric surgery [16]. In our study, MVPA increased on average by 8 min/d, with large
247 between-subject variability in both the direction and magnitude of change. Six months after
248 RYGB, two-third of patients were compliant with the latest US PA guidelines [25], and only
249 20% were compliant with previous recommendations that considered only MVPA
250 accumulated in bouts of 10 minutes or longer [4]. Some previous studies have shown no
251 significant change in accelerometry-assessed PA in the first months after bariatric surgery
252 [21, 27-30], in contrast with a number of studies that have consistently reported increases in
253 self-reported PA [31]. Objectively-measured PA data suggest that weight loss alone might
254 not be sufficient to substantially increase habitual PA. Behavioral interventions targeting
255 daily PA might therefore be needed to help patients undergoing bariatric surgery reaching the
256 recommended level of PA.

257

258 Another important finding of this study was that MVPA accumulated in bouts represented
259 less than 10% of total MVPA before RYGB, and less than 20% six months after RYGB.
260 Short bouts of MVPA were therefore largely predominant both before and after RYGB.
261 Similar patterns of MVPA have been described in previous studies, with ≥ 10 -min bouts
262 MVPA representing 9% to 22% of total MVPA in patients after bariatric surgery [21, 28, 32,
263 33]. Prolonged bouts of MVPA appear more prevalent in normal-weight or adults with
264 overweight, in whom MVPA accumulated in ≥ 10 -min bouts has been found to reach up to
265 40% of total MVPA [34]. Growing evidence suggests that MVPA is associated with health
266 benefits, independently of bout duration: short bouts of MVPA have been associated with a
267 reduction in mortality risk [35], BMI or adiposity, blood pressure, blood lipids and with
268 improved glycemic control [36]. However, there is no consensus as to whether prolonged
269 bouts of MVPA are more strongly associated with health outcomes than short bouts [36]. Our
270 data suggest that modest improvement in total MVPA might provide additional benefits on
271 CRF after bariatric surgery, even though short bouts of MVPA remain predominant. In these
272 subjects, maintaining long bouts of MVPA might be a particularly challenging task.
273 Therefore, promoting both incidental and prolonged PA may represent an important and
274 reachable objective in patients with severe obesity undergoing bariatric surgery.

275

276 Strengths of the study include the objective measurement of CRF and PA before and after
277 RYGB in a homogeneous group of women who received the same surgical procedure. The
278 use of min-by-min accelerometry data provided new insights about accumulation of PA in
279 these subjects, especially regarding bout analysis. Although the most widely used
280 accelerometers in clinical and population studies, Actigraph accelerometers have not been
281 specifically validated in subjects with severe obesity. Only women were included in the
282 study, and our subjects underwent only one type of bariatric procedure, which prevents us

283 from extrapolating results to all obese subjects and to those undergoing other types of
284 bariatric surgery. In addition, patients were initially included in a clinical trial although we
285 did not include subjects from the exercise training group in our analyses.

286

287 **Conclusion**

288 This study shows that CRF relative to body weight tends to increase in the early first months
289 following bariatric surgery, but that absolute CRF decreases significantly. A significant,
290 although modest, increase in habitual PA was also found. Changes in both CRF and PA were
291 characterized by large inter-individual variability in both the direction and magnitude of
292 change. The change in CRF was positively related to the change in PA, suggesting that
293 habitual PA contributes to the improvement in physical fitness after bariatric surgery. These
294 findings highlight the need to identify effective interventions for promoting PA after bariatric
295 surgery that can be incorporated into routine clinical care.

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303

304 **Blinded conflict of interest disclosure statement**

305 Author 1, author 2, author 3, author 4, author 5 and author 6 declare no conflicts of interest.

306

307 **Statements regarding ethics and consent**

308 All procedures performed in studies involving human participants were in accordance with
309 the ethical standards of the institutional and/or national research committee and with the 1964
310 Helsinki declaration and its later amendments or comparable ethical standards.

311

312 **References**

- 313 1. Mechanick JI, Youdim A, Jones DB, Garvey WT, Hurley DL, McMahon MM, et al.
314 Clinical practice guidelines for the perioperative nutritional, metabolic, and nonsurgical
315 support of the bariatric surgery patient--2013 update: cosponsored by American Association
316 of Clinical Endocrinologists, The Obesity Society, and American Society for Metabolic &
317 Bariatric Surgery. *Obesity (Silver Spring)*. 2013 Mar;21 Suppl 1:S1-27. PubMed PMID:
318 23529939. Pubmed Central PMCID: PMC4142593.
- 319 2. Sjostrom L, Peltonen M, Jacobson P, Sjostrom CD, Karason K, Wedel H, et al.
320 Bariatric surgery and long-term cardiovascular events. *JAMA*. 2012 Jan 4;307(1):56-65.
321 PubMed PMID: 22215166.
- 322 3. Ross R, Blair SN, Arena R, Church TS, Despres JP, Franklin BA, et al. Importance of
323 Assessing Cardiorespiratory Fitness in Clinical Practice: A Case for Fitness as a Clinical
324 Vital Sign: A Scientific Statement From the American Heart Association. *Circulation*. 2016
325 Dec 13;134(24):e653-e99. PubMed PMID: 27881567.
- 326 4. U.S. Department of Health and Human Services. Physical activity guidelines for
327 Americans. Washington: 2008.
- 328 5. ACSM. American College of Sports Medicine's Guidelines for Exercise Testing and
329 Prescription. 9th edition. Baltimore, MD: Lippincott; 2014.
- 330 6. Kodama S, Saito K, Tanaka S, Maki M, Yachi Y, Asumi M, et al. Cardiorespiratory
331 fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy

332 men and women: a meta-analysis. JAMA. 2009 May 20;301(19):2024-35. PubMed PMID:
333 19454641.

334 7. Fogelholm M. Physical activity, fitness and fatness: relations to mortality, morbidity
335 and disease risk factors. A systematic review. *Obes Rev.* 2010 Mar;11(3):202-21. PubMed
336 PMID: 19744231.

337 8. McCullough PA, Gallagher MJ, Dejong AT, Sandberg KR, Trivax JE, Alexander D,
338 et al. Cardiorespiratory fitness and short-term complications after bariatric surgery. *Chest.*
339 2006 Aug;130(2):517-25. PubMed PMID: 16899853.

340 9. Seres L, Lopez-Ayerbe J, Coll R, Rodriguez O, Vila J, Formiguera X, et al. Increased
341 exercise capacity after surgically induced weight loss in morbid obesity. *Obesity (Silver*
342 *Spring).* 2006 Feb;14(2):273-9. PubMed PMID: 16571853.

343 10. Kanoupakis E, Michaloudis D, Fraidakis O, Parthenakis F, Vardas P, Melissas J. Left
344 ventricular function and cardiopulmonary performance following surgical treatment of
345 morbid obesity. *Obes Surg.* 2001 Oct;11(5):552-8. PubMed PMID: 11594094.

346 11. de Souza SA, Faintuch J, Sant'anna AF. Effect of weight loss on aerobic capacity in
347 patients with severe obesity before and after bariatric surgery. *Obes Surg.* 2010
348 Jul;20(7):871-5. PubMed PMID: 20414740.

349 12. Wilms B, Ernst B, Thurnheer M, Weisser B, Schultes B. Differential changes in
350 exercise performance after massive weight loss induced by bariatric surgery. *Obes Surg.* 2013
351 Mar;23(3):365-71. PubMed PMID: 23093471.

352 13. Lund MT, Hansen M, Wimmelmann CL, Taudorf LR, Helge JW, Mortensen EL, et
353 al. Increased post-operative cardiopulmonary fitness in gastric bypass patients is explained by
354 weight loss. *Scand J Med Sci Sports.* 2016 Dec;26(12):1428-34. PubMed PMID: 26635069.

- 355 14. Neunhaeuserer D, Gasperetti A, Savalla F, Gobbo S, Bullo V, Bergamin M, et al.
356 Functional Evaluation in Obese Patients Before and After Sleeve Gastrectomy. *Obes Surg.*
357 2017 Dec;27(12):3230-9. PubMed PMID: 28589528.
- 358 15. Bouchard C, Rankinen T. Individual differences in response to regular physical
359 activity. *Med Sci Sports Exerc.* 2001 Jun;33(6 Suppl):S446-51; discussion S52-3. PubMed
360 PMID: 11427769.
- 361 16. Bellicha A, Ciangura C, Poitou C, Portero P, Oppert JM. Effectiveness of exercise
362 training after bariatric surgery-a systematic literature review and meta-analysis. *Obes Rev.*
363 2018 Nov;19(11):1544-56. PubMed PMID: 30156007.
- 364 17. da Silva ALG, Sardeli AV, Andre LD, Severin R, de Oliveira CR, Hassan C, et al.
365 Exercise Training Does Improve Cardiorespiratory Fitness in Post-Bariatric Surgery Patients.
366 *Obes Surg.* 2019 Feb 1. PubMed PMID: 30706319.
- 367 18. Tettero OM, Aronson T, Wolf RJ, Nuijten MAH, Hopman MTE, Janssen IMC.
368 Increase in Physical Activity After Bariatric Surgery Demonstrates Improvement in Weight
369 Loss and Cardiorespiratory Fitness. *Obes Surg.* 2018 Aug 13;28(12):3950-7. PubMed PMID:
370 30105664.
- 371 19. Oppert JM, Bellicha A, Roda C, Bouillot JL, Torcivia A, Clement K, et al. Resistance
372 training and protein supplementation increase strength after bariatric surgery: a randomized
373 controlled trial. *Obesity (Silver Spring).* 2018;26(11):1709-20.
- 374 20. Jensen MD, Ryan DH, Apovian CM, Ard JD, Comuzzie AG, Donato KA, et al. 2013
375 AHA/ACC/TOS guideline for the management of overweight and obesity in adults: a report
376 of the American College of Cardiology/American Heart Association Task Force on Practice
377 Guidelines and The Obesity Society. *Circulation.* 2014 Jun 24;129(25 Suppl 2):S102-38.
378 PubMed PMID: 24222017.

- 379 21. Bond DS, Jakicic JM, Unick JL, Vithiananthan S, Pohl D, Roye GD, et al. Pre- to
380 postoperative physical activity changes in bariatric surgery patients: self report vs. objective
381 measures. *Obesity (Silver Spring)*. 2010 Dec;18(12):2395-7. PubMed PMID: 20379143.
382 Pubmed Central PMCID: 3909967.
- 383 22. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and
384 Applications, Inc. accelerometer. *Med Sci Sports Exerc*. 1998 May;30(5):777-81. PubMed
385 PMID: 9588623.
- 386 23. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical
387 activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008
388 Jan;40(1):181-8. PubMed PMID: 18091006.
- 389 24. Tudor-Locke C, Brashear MM, Johnson WD, Katzmarzyk PT. Accelerometer profiles
390 of physical activity and inactivity in normal weight, overweight, and obese U.S. men and
391 women. *Int J Behav Nutr Phys Act*. 2010;7:60. PubMed PMID: 20682057. Pubmed Central
392 PMCID: PMC2924256.
- 393 25. Piercy KL, Troiano RP, Ballard RM, Carlson SA, Fulton JE, Galuska DA, et al. The
394 Physical Activity Guidelines for Americans. *JAMA*. 2018 Nov 20;320(19):2020-8. PubMed
395 PMID: 30418471.
- 396 26. Kaminsky LA, Imboden MT, Arena R, Myers J. Reference Standards for
397 Cardiorespiratory Fitness Measured With Cardiopulmonary Exercise Testing Using Cycle
398 Ergometry: Data From the Fitness Registry and the Importance of Exercise National
399 Database (FRIEND) Registry. *Mayo Clin Proc*. 2017 Feb;92(2):228-33. PubMed PMID:
400 27938891.
- 401 27. Giusti V, Theytaz F, Di Vetta V, Clarisse M, Suter M, Tappy L. Energy and
402 macronutrient intake after gastric bypass for morbid obesity: a 3-y observational study

403 focused on protein consumption. *Am J Clin Nutr.* 2016 Jan;103(1):18-24. PubMed PMID:
404 26675775.

405 28. Berglind D, Willmer M, Eriksson U, Thorell A, Sundbom M, Udden J, et al.
406 Longitudinal assessment of physical activity in women undergoing Roux-en-Y gastric
407 bypass. *Obes Surg.* 2015 Jan;25(1):119-25. PubMed PMID: 24934315.

408 29. Afshar S, Seymour K, Kelly SB, Woodcock S, van Hees VT, Mathers JC. Changes in
409 physical activity after bariatric surgery: using objective and self-reported measures. *Surg*
410 *Obes Relat Dis.* 2016 Sep 13;13(3):474-83. PubMed PMID: 27771316.

411 30. Liu X, Lagoy A, Discenza I, Papineau G, Lewis E, Braden G, et al. Metabolic and
412 neuroendocrine responses to Roux-en-Y gastric bypass. I: energy balance, metabolic changes,
413 and fat loss. *J Clin Endocrinol Metab.* 2012 Aug;97(8):E1440-50. PubMed PMID: 22585089.

414 31. Herring LY, Stevinson C, Davies MJ, Biddle SJ, Sutton C, Bowrey D, et al. Changes
415 in physical activity behaviour and physical function after bariatric surgery: a systematic
416 review and meta-analysis. *Obes Rev.* 2016 Mar;17(3):250-61. PubMed PMID: 26783103.

417 32. Bond DS, Jakicic JM, Vithiananthan S, Thomas JG, Leahey TM, Sax HC, et al.
418 Objective quantification of physical activity in bariatric surgery candidates and normal-
419 weight controls. *Surg Obes Relat Dis.* 2010 Jan-Feb;6(1):72-8. PubMed PMID: 19837009.
420 Pubmed Central PMCID: 2818132.

421 33. King WC, Chen JY, Bond DS, Belle SH, Courcoulas AP, Patterson EJ, et al.
422 Objective assessment of changes in physical activity and sedentary behavior: Pre- through 3
423 years post-bariatric surgery. *Obesity (Silver Spring).* 2015 Jun;23(6):1143-50. PubMed
424 PMID: 26010326. Pubmed Central PMCID: PMC4445467.

425 34. Glazer NL, Lyass A, Esliger DW, Blease SJ, Freedson PS, Massaro JM, et al.
426 Sustained and shorter bouts of physical activity are related to cardiovascular health. *Med Sci*

427 Sports Exerc. 2013 Jan;45(1):109-15. PubMed PMID: 22895372. Pubmed Central PMCID:
428 PMC4166425.

429 35. Saint-Maurice PF, Troiano RP, Matthews CE, Kraus WE. Moderate-to-Vigorous
430 Physical Activity and All-Cause Mortality: Do Bouts Matter? J Am Heart Assoc. 2018 Mar
431 22;7(6). PubMed PMID: 29567764.

432 36. PAGAC. *Physical Activity Guidelines Advisory Committee Report*. Washington, DC :
433 US Department of Health and Human Services. 2018.

434

435 **Figure caption**

436

437 **Figure 1.**

438 **Title:** Correlation between change in absolute $\dot{V}O_{2peak}$ (a) or relative $\dot{V}O_{2peak}$ (b) and
439 change in total MVPA six months after Roux-en-Y gastric bypass

440 **Caption:** Pearson correlation (r) adjusted on age and preoperative BMI

441

442 **Table 1. Characteristics of study participants before and after RYGB (N=45)**

	Before RYGB	After RYGB	Change Mean (SD)	P-value
Age, years	43.0 (38.0-51.0)	--	--	--
<u>BODY COMPOSITION</u> (N=45/53)				
Body weight, kg	114.3 (104.2-129.4)	89.3 (77.3-100.2)	-27.5 (7.9)	<0.001
BMI, kg/m ²	42.6 (40.0-45.5)	32.7 (29.8-36.0)	-10.2 (2.7)	<0.001
Body fat, %	50.2 (48.0-52.0)	43.1 (40.2-45.8)	-7.2 (3.2)	<0.001
Fat mass, kg	57.6 (52.7-66.2)	39.7 (33.3-43.5)	-19.8 (4.7)	<0.001
LBM, kg	56.4 (51.8-61.2)	47.9 (44.1-52.0)	-8.4 (3.0)	<0.001
<u>CARDIORESPIRATORY</u>				
<u>FITNESS</u> (N=41/53)				
Absolute $\dot{V}O_{2peak}$, L/min	2.13 (1.77-2.47)	1.78 (1.38-2.25)	-0.35 (0.50)	<0.001
$\dot{V}O_{2peak}$ relative to body mass, mL/kg/min	18.8 (16.2-21.7)	20.2 (16.6-24.3)	1.7 (5.3)	0.059
$\dot{V}O_{2peak}$ relative to LBM, mL/kgLBM/min	38.8 (32.2-42.6)	35.1 (32.2-45.0)	-1.3 (10.2)	0.509
<u>PHYSICAL ACTIVITY</u> (N=45/53)				
Number of valid days	7 (6-7)	7 (6-7)	-0.1 (1.3)	0.596
Wear time, h/d	13.3 (12.3-14.1)	12.9 (12.1-14.3)	-0.1 (1.5)	0.778
Counts, count/min	303 (238-373)	296 (249-406)	29.3 (126.5)	0.337
Daily steps, steps/d	5,930 (4,964-7,726)	7,244 (5,735-9,757)	1,275 (3,164)	0.024
Sedentary time, min/d	484.9 (423.7-537.0)	501.6 (416.1-531.7)	-1.3 (78.1)	0.612
Light-intensity PA, min/d	265.0 (225.4-344.9)	263.2 (229.1-317.8)	-11.1 (71.2)	0.491
Moderate-intensity PA, min/d	25.0 (16.7-35.9)	30.7 (17.9-45.4)	6.8 (17.9)	0.028
Vigorous-intensity PA, min/d	0 (0-0)	0 (0-0.1)	0.8 (3.0)	0.042
MVPA, min/d	25.0 (16.7-36.0)	31.1 (17.9-45.4)	7.6 (19.3)	0.024
MVPA in \geq 10-min bouts, min/wk	20 (0-92)	45 (20-91)	38.1 (110.2)	0.034
MVPA in \geq 10-min bouts, % total MVPA	7.1 (0.0-26.4)	15.9 (6.8-30.1)	+5.6 (15.0)	0.014

443 Data are median (25th-75th percentile) unless otherwise stated.

444 P-value from Wilcoxon signed-rank test; bold values indicate significance with P<0.05.

445 Censored steps were calculated by censoring steps taken at an intensity <500 counts/min

446 [24].

447 Abbreviations: BMI, body mass index; LBM, lean body mass; RYGB, Roux-en-Y gastric

448 bypass; PA, physical activity; MVPA, moderate-to-vigorous physical activity.

449