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

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## ► To cite this version:

Alice Bellicha, Cécile Ciangura, Céline Roda, Adriana Torcivia, Pierre Portero, et al.. Changes in Cardiorespiratory Fitness After Gastric Bypass: Relations with Accelerometry-Assessed Physical Activity. *Obesity Surgery*, 2019, 29 (9), pp.2936-2941. 10.1007/s11695-019-03932-2 . hal-03640794

**HAL Id: hal-03640794**

**<https://hal.science/hal-03640794>**

Submitted on 13 Apr 2022

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1 This version of the article has been accepted for publication, after peer review (when  
2 applicable) and is subject to Springer Nature's AM terms of use, but is not the Version of  
3 Record and does not reflect post-acceptance improvements, or any corrections. The Version  
4 of Record is available online at: [https://link.springer.com/article/10.1007/s11695-019-03932-](https://link.springer.com/article/10.1007/s11695-019-03932-2)  
5 [2 \[10.1007/s11695-019-03932-2\]](https://link.springer.com/article/10.1007/s11695-019-03932-2)

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

8 **Running title:** Fitness after gastric bypass

9 **Manuscript type:** original

10

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44 **Acknowledgements**

45 This work was supported by PHRC Programme Hospitalier de Recherche Clinique-Ile de  
46 France (AOR 09 059).  
47 We recognize the contribution of the Clinical Research Unit (Unité de Recherche Clinique  
48 URC), Pitie-Salpetriere Hospital (AP-HP), Paris, France, in data acquisition and  
49 management.  
50 We express our thanks to the patients for their participation in this study.

51

52 **Non-blinded version of your COI:** No conflicts of interest

53

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 [P<sub>25</sub>-P<sub>75</sub>] age: 43.0 [38.0-51.0] y, BMI: 42.6 [40.0-45.5]  
70 kg/m<sup>2</sup>) 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  $\geq 500$  counts/min were registered [24]. Patients were considered  
164 compliant to the 2008 US PA guidelines when MVPA accumulated in  $\geq 10$ -min bouts was  
165  $\geq 150$  min/wk [4] and compliant to the 2018 US PA guidelines when total MVPA was  $\geq 150$   
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 (25<sup>th</sup>-75<sup>th</sup> 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  $\geq 10$ -min bouts increased on average by more than two-fold (P<0.05). The  
210 proportion of MVPA accumulated in  $\geq 10$ -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  $\geq 10$   
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  $\geq 10$ -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  $\geq 10$ -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.

296

### 297 **Acknowledgements**

298 This work was supported by PHRC Programme Hospitalier de Recherche Clinique-Ile de  
299 France (AOR 09 059).

300 We recognize the contribution of the Unité de Recherche Clinique/Clinical Unit Research,  
301 Pitie-Salpetriere Hospital, Paris, France, in data acquisition and management.

302 We express our thanks to the patients for their participation in this study

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

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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)**

	<b>Before RYGB</b>	<b>After RYGB</b>	<b>Change</b> Mean (SD)	<b>P-value</b>
Age, years	43.0 (38.0-51.0)	--	--	--
<b><u>BODY COMPOSITION</u></b> (N=45/53)				
Body weight, kg	114.3 (104.2-129.4)	89.3 (77.3-100.2)	-27.5 (7.9)	<b>&lt;0.001</b>
BMI, kg/m <sup>2</sup>	42.6 (40.0-45.5)	32.7 (29.8-36.0)	-10.2 (2.7)	<b>&lt;0.001</b>
Body fat, %	50.2 (48.0-52.0)	43.1 (40.2-45.8)	-7.2 (3.2)	<b>&lt;0.001</b>
Fat mass, kg	57.6 (52.7-66.2)	39.7 (33.3-43.5)	-19.8 (4.7)	<b>&lt;0.001</b>
LBM, kg	56.4 (51.8-61.2)	47.9 (44.1-52.0)	-8.4 (3.0)	<b>&lt;0.001</b>
<b><u>CARDIORESPIRATORY</u></b>				
<b><u>FITNESS</u></b> (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)	<b>&lt;0.001</b>
$\dot{V}O_{2peak}$ 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
<b><u>PHYSICAL ACTIVITY</u></b> (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)	<b>0.024</b>
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)	<b>0.028</b>
Vigorous-intensity PA, min/d	0 (0-0)	0 (0-0.1)	0.8 (3.0)	<b>0.042</b>
MVPA, min/d	25.0 (16.7-36.0)	31.1 (17.9-45.4)	7.6 (19.3)	<b>0.024</b>
MVPA in $\geq$ 10-min bouts, min/wk	20 (0-92)	45 (20-91)	38.1 (110.2)	<b>0.034</b>
MVPA in $\geq$ 10-min bouts, % total MVPA	7.1 (0.0-26.4)	15.9 (6.8-30.1)	+5.6 (15.0)	<b>0.014</b>

443 Data are median (25<sup>th</sup>-75<sup>th</sup> 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