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## ► To cite this version:

Louis Toulouse, Patrick Mucci, Thierry Pezé, Gautier Zunquin. Influence of grade of obesity on the achievement of VO<sub>2</sub>max using an incremental treadmill test in youths. *Journal of Sports Sciences*, 2021, 39 (15), pp.1717-1722. 10.1080/02640414.2021.1898093 . hal-03183883

**HAL Id: hal-03183883**

**<https://hal.science/hal-03183883>**

Submitted on 29 Mar 2021

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1 **Influence of grade of obesity on the achievement of VO2max using an**  
2 **incremental treadmill test in youths**

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16

17 **Influence of grade of obesity on the achievement of  $VO_{2max}$  using an**  
18 **incremental treadmill test in youths**

19 The purpose of this study was to analyze the influence of grade of obesity on the  
20 probability of achieving a  $VO_2$  plateau and threshold secondary criteria for  
21 verifying  $VO_{2max}$  during a treadmill walk test in youths with obesity. Therefore,  
22 72 youths with obesity (aged 8-16) performed an incremental treadmill walk test  
23 to exhaustion during which oxygen uptake ( $VO_2$ ), minute ventilation (VE), heart  
24 rate (HR) and rating of perceived exertion were continuously measured. HR  
25 corresponding to a “hard” level of perceived exertion was reported and expressed  
26 as a percentage of the predicted  $HR_{max}$ . The rate of achievement of criteria for  
27 validation  $VO_{2max}$  ( $VO_2$  plateau;  $HR > 95\%$  theoretical  $HR_{max}$ ;  $RER > 1.0$ ; rating of  
28 perceived exertion  $\geq$  “hard”) was compared between participants with grade I and  
29 grade II obesity. 37% of the participants achieved a  $VO_2$  plateau and 23%  
30 achieved both an  $HR > 95\%$  and  $RER > 1.0$ . Youths with grade II obesity had  
31 lower minute ventilation ( $p < 0.01$ ) tended to be more likely to reach an  $HR > 95\%$   
32 (OR = 0.33 ;  $P = 0.06$ ) and a “hard” rating of perceived exertion than grade I (OR  
33 = 4.5 ;  $P = 0.07$ ). However, there was no influence of grade of obesity on the  
34 achievement of  $VO_2$  plateau, and  $RER > 1.0$ . A higher grade of obesity was related  
35 to a lower peak in minute ventilation normalized by fat-free mass, lower peak  
36 heart rates and premature reaching of a “hard” rating of perceived exertion.  
37 Therefore, youths with higher grades of obesity might be less likely to display  
38 maximal heart rate during an incremental treadmill test, probably due to higher  
39 ventilatory constraints and higher ratings of perceived exertion.

40 Keywords: children ; adolescents ; obesity ; treadmill ;  $VO_{2max}$

41 Words count (text only) : 3102

42 Number of table : 2

43

44 **INTRODUCTION**

45 Cardiorespiratory fitness is one of the best predictors of all-cause mortality in adults<sup>1</sup>,  
46 especially when it is normalized by fat-free mass<sup>2</sup>. Cardiorespiratory fitness is assessed  
47 by the maximal oxygen uptake ( $VO_{2max}$ ), which is the highest value of  $VO_2$  clinically  
48 attainable during a progressive cycling or treadmill test conducted to exhaustion<sup>3</sup>. Since  
49 walking is more representative of free-living physical activities, treadmill walk tests are  
50 mostly used to assess the  $VO_{2max}$  in youth with obesity<sup>4-6</sup>. During these tests, the speed  
51 is constant and usually between 3.5 and 5 km.h<sup>-1</sup>, which is close to the preferred  
52 walking speed in this population<sup>7</sup>. The intensity is increased by increasing the slope,  
53 amounting to 1 or 2% per minute<sup>4,5</sup>. To verify the achievement of  $VO_{2max}$  (i.e., a  
54 maximal aerobic effort) during this type of test, it was proposed that youths with obesity  
55 should reach at least one of the three following physiological criteria: 1) the presence of  
56 a  $VO_2$  plateau; 2) a heart rate > 200bpm or 95% $HR_{max}$ ; 3) a respiratory exchange ratio >  
57 1.0. According to these criteria, Gutin et al. found that 66 out of 80 participants (~ 83%)  
58 reached  $VO_{2max}$ <sup>4</sup>. Using the same protocol, a study<sup>6</sup> found that 29% of adolescents with  
59 grade II obesity achieved a  $VO_2$  plateau. However, the rates of achievement of  
60 secondary threshold criteria were not specified. Finally, one study<sup>5</sup> did not specify the  
61 criteria<sup>4</sup> used to verify the achievement of  $VO_{2max}$ , which does not allow to determine  
62 the extent to which their treadmill protocol elicited a maximal aerobic effort. Since  
63  $VO_{2max}$  remains the gold standard for monitoring aerobic fitness in youths with obesity<sup>8</sup>,  
64 it is necessary to ensure that a maximal aerobic effort has been made during the test.  
65 However, there is still a lack of transparency regarding the criteria used to ensure that a  
66 maximal aerobic effort has been made during treadmill walk tests in youths with  
67 obesity. Furthermore, no study has investigated the influence of grade of obesity on the  
68 probability of achieving  $VO_{2max}$  during this type of protocol. Thus, further studies are

69 needed to better understand the mechanisms associated with the non-achievement of a  
70  $VO_2$  plateau and secondary threshold criteria for verifying  $VO_{2max}$  in youth with  
71 obesity.

72 Therefore, this study aimed to assess the influence of grade of obesity on the probability  
73 of achieving a  $VO_2$  plateau and secondary threshold criteria for verifying  $VO_{2max}$  during  
74 an incremental treadmill walk test in youth with obesity.

## 75 **METHODS**

### 76 *Participants*

77 72 youths with obesity were included in this study. The inclusion criteria were an age  
78 between 8 and 16 years old and a BMI superior to the 85<sup>th</sup> percentile of the IOTF  
79 standards for BMI, defining grade I obesity in youths<sup>9</sup>. These youths are oriented by  
80 their practitioner towards obesity management networks (including the hospital center  
81 and associations) where they are offered to follow care adapted to their needs. During  
82 their inclusion appointment to the program, the youths participants and their parents  
83 received an oral and written explanation of the experimental procedure and the  
84 objectives of the study. For youths, the information notice was written in a language  
85 adapted to their level of understanding. After a reflection time of at least one week  
86 following the inclusion visit, the youths and the voluntary parents signed a written  
87 consent summarizing the information relating to the study.

### 88 *General procedure*

89 The experiments took place in the department of pulmonary medicine of the hospital  
90 center in the presence of a specialist doctor. Participants were called in the morning  
91 between 10 a.m. and 12 p.m. or in the afternoon between 3 p.m. and 7 p.m., at least two

92 hours after their last food intake to avoid digestive discomfort during the test. Parents  
 93 were asked to make sure that their youths did not exercise intensively during the 48  
 94 hours preceding the appointment. Before the experiments, the participants were  
 95 measured in standing and seated positions using a stadiometer. Then, the body weight  
 96 and composition were measured using bioimpedance-analysis (Tanita DC-360, Japan).  
 97 These measurements allowed us to obtain an estimate of their body composition (fat-  
 98 free mass and fat mass) and to calculate their BMI z-score based on the IOTF<sup>9</sup> and  
 99 WHO<sup>10</sup> standards. Participants who had a BMI z-score between 1 and 2 (not included)  
 100 according to the IOTF standards were categorized into "grade I obesity", whereas those  
 101 who had a BMI z-score > 2 were categorized into "grade II obesity". From the  
 102 anthropometrical measurements, the Age of Peak Height Velocity – age of PHV (also  
 103 called “Maturity Offset”) was estimated using the following sex-specific equations  
 104 provided by Mirwald et al.<sup>11</sup> :

$$\text{Eq. 1 : Maturity Offset (boys) = } -9.236$$

$$+ 0.0002708 \cdot \text{Leg Length and Sitting Height interaction}$$

$$- 0.001663 \cdot \text{Age and Leg Length interaction}$$

$$+ 0.007216 \cdot \text{Age and Sitting Height interaction}$$

$$+ 0.02292 \cdot \text{Weight by Height ratio}$$

105

$$\text{Eq. 2 : Maturity Offset (girls) = } - 9.376$$

$$+ 0.0001882 \cdot \text{Leg Length and Sitting Height interaction}$$

$$+ 0.0022 \cdot \text{Age and Leg Length interaction}$$

$$+ 0.005841 \cdot \text{Age and Sitting Height interaction}$$

$$- 0.002658 \cdot \text{Age and Weight interaction}$$

$$+ 0.07693 \cdot \text{Weight by Height ratio}$$

106

107 Then, age from the peak height velocity (age from PHV) was estimated by subtracting  
108 the estimated age of PHV by the chronological age. A negative value indicates that the  
109 PHV has not occurred yet<sup>11</sup>. The maturity offset and age from PHV were used as an  
110 indicator of the maturity of the participants.

### 111 *Incremental exercise*

112 The incremental treadmill protocol consisted of performing a 3-minute warm-up at 0%  
113 slope and a speed between 3.0 to 4.5 km.h<sup>-1</sup> so that the participant reached a heart-rate  
114 (HR) steady-state at  $60 \pm 5\%$  (110-130 bpm) of the predicted maximum HR estimated  
115 with the formula of Tanaka<sup>12</sup> [HRmax = 208 - 0.7 \* age]. Normalizing the starting  
116 speed by the HR was intended to ensure an equitable starting intensity between  
117 individuals and optimal exercise duration (> 5 minutes excluding warm-up) for all  
118 participants<sup>13</sup>. During the first 5 minutes, the slope increased by 2% per minute and the  
119 speed was kept constant. From the sixth minute, the slope was maintained at 10% and  
120 the speed increased by 0.3 km.h<sup>-1</sup> for a starting speed between 3.0 km.h<sup>-1</sup> and 3.7 km.h<sup>-1</sup>  
121 or by 0.4 km.h<sup>-1</sup> for a starting speed between 3.7 and 4.5 km.h<sup>-1</sup>. This protocol was  
122 selected because high treadmill grades would be associated with an increased failure to  
123 achieve VO<sub>2max</sub><sup>14</sup>. The test ended when the participant declared that he was no longer  
124 able to continue the test despite the encouragement of the experimenter.

### 125 *Measurement and processing of data*

126 During exercise, HR was measured using a recently validated optical heart rate monitor  
127 (Polar OH1, Finland)<sup>15</sup> positioned at the left wrist. The peak heart rate (HR<sub>peak</sub>)  
128 observed during the test was the highest value averaged on 3 points. The VO<sub>2</sub> was  
129 measured breath-by-breath using a portable respiratory gas analyzer (Cosmed K4b2,

130 Italy) calibrated before the exercises following the manufacturer's recommendations.  
131 The  $VO_{2peak}$  and peak in minute ventilation ( $VE_{peakBM}$ ) were reported as the highest  
132 values over a 30s moving-averaged interval, as recently recommended in youths<sup>16</sup>.  
133 Rating of perceived exertion (RPE) was continuously assessed using the CR-10 Borg  
134 scale previously used in youths with obesity<sup>5</sup>. This scale describes the difficulties of  
135 breathing from level 1 ("not at all") to 10 ("maximal"). The HR measured when the  
136 participant declared a level of 5/10 on the scale - corresponding to the "hard" item  
137 ( $HR_{RPEhard}$ ) - was reported and expressed as a percentage of the individual predicted  
138  $HR_{max}$ . We chose this indicator to get information about the level of physiological stress  
139 that each participant was able to tolerate before the effort was "hard", a term that has  
140 more clinically significance in youths<sup>17</sup>.

#### 141 ***Criteria for verifying $VO_{2max}$***

142 Following previous studies in youths with obesity<sup>4,6</sup>, the present cardiorespiratory-based  
143 criteria for verifying  $VO_{2max}$  were used: primary criterion = presence of a  $VO_2$  plateau;  
144 secondary threshold criteria =  $HR > 95\%$  of theoretical maximal HR and  $RER > 1.0$ .  
145 Participants were considered as  $VO_{2max}$  achievers when at least the  $VO_2$  plateau or both  
146 the secondary threshold criteria were met. The presence of a  $VO_2$  plateau was  
147 characterized when the increase in  $VO_2$  during the last completed minute of effort was  
148 strictly less than 50% of the increase observable during the penultimate minute of effort.  
149 This method based on the individual workload/ $VO_2$  relationship was recently  
150 recommended<sup>18</sup> and used to detect  $VO_2$  plateaus in adults with obesity<sup>19</sup>. A fourth  
151 criterion based on the achievement of an  $RPE \geq 5$  (item "hard") was also used. This  
152 criterion was used as a measurement of the psychological tolerance to the treadmill test.  
153 Conversely, the criteria based on volitional exhaustion was not used because the latter is



154 determined rather by the experimenter than the participant, limiting the possibilities of  
155 inter-study comparisons.

### 156 *Statistical analysis*

157 The data were analyzed on the R software (version 3.6.2). The normality and  
158 homogeneity of the distributions were checked respectively with the Shapiro-Wilk test  
159 and the F test of Snedecor. Firstly, the clinical characteristics and peak exercise data of  
160 participants were compared between those who had grade I and those who had grade II  
161 obesity using Student t-tests and Cohen's *d*. Secondly, the number and rate of  
162 participants who met the criteria for verifying  $VO_{2max}$  were calculated and reported  
163 according to the grade of obesity. Chi-Square tests were performed to analyze the  
164 differences in the rate of achievement of each criterion according to the grade of  
165 obesity. If significant differences were found, logistic regression analysis was  
166 performed to examine the association between the grade of obesity and the achievement  
167 of each criterion. The significance threshold was set at  $P < 0.05$ .

168

### 169 **Results**

170 Participants' characteristics, cardiorespiratory, and perceptual responses are shown in  
171 table 1. Youths with grade II obesity were less mature ( $P < 0.05$ ,  $d = 0.5$ ), heavier  
172 ( $d = 1.25$ ) and had a higher BMI z-score ( $d = 4.47$ ) and percentage of body fat ( $d = 2.38$ )  
173 than grade I ( $P < 0.001$  for each parameter).  $VE_{peak}$  divided by body mass ( $P < 0.001$ ,  
174  $d = 1.34$ ), fat-free mass ( $P < 0.05$ ,  $d = 0.72$ ) and  $VO_{2peak}$  divided by body mass ( $P < 0.01$ ,  
175  $d = 1.03$ ) were lower in youths with grade II obesity than grade I. Conversely, no

176 between-groups significant differences were found regarding  $HR_{peak}$ ,  $HR_{RPEhard}$ , and  
177  $RER_{peak}$ .

178 \*\*\* Table 1 here \*\*\*

179 Table 2 summarizes results regarding the achievement of both primary and secondary  
180 threshold criteria for verifying  $VO_{2max}$  in grade II vs. grade I obesity. A  $VO_2$  plateau  
181 was met by 38% of the participants and 23% met both an  $HR > 95\%HR_{max}$  and an  $R$   
182  $RER > 1.0$ . According to the criteria for verifying  $VO_{2max}$  used in children with obesity,  
183 54% of the participants would have reached  $VO_{2max}$  during the test. An  $RPE > 5/10$  was  
184 reached by 92% of the participants. According to the Chi-square tests, youths with grade  
185 II obesity tended to be less likely to display an  $HR > 95\%HR_{max}$  ( $OR = 0.33$ ;  $P=0.06$ )  
186 and more likely to indicate an  $RPE > 5/10$  ( $OR = 4.5$ ;  $P=0.07$ ) than grade I. However, no  
187 significant differences were found regarding the achievement of a  $VO_2$  plateau  
188 ( $P=0.33$ ),  $RER > 1.0$  ( $P=0.27$ ), or  $VO_{2max}$  ( $P=0.44$ ).

189 \*\*\* Table 2 here \*\*\*

## 190 **Discussion**

191 The main purpose of this study was to study the influence of the grade of obesity on the  
192 probability to meet the primary and secondary threshold criteria for verifying  $VO_{2max}$   
193 during a treadmill test. The secondary purpose was to measure the cardiorespiratory and  
194 perceptual responses to this test in the youth with obesity, which is an under-evaluated  
195 population. The main findings of this study are that 1) youths with grade II obesity were  
196 less likely to display an  $HR > 95\%HR_{max}$  and 2) youths with grade II obesity were more  
197 likely to indicate an RPE reflecting a “hard” level of effort than grade I. Furthermore,

198 youth with grade II obesity displayed lower peaks in minute ventilation normalized by  
199 the fat-free mass than grade I.

200

201 Adults suffering from chronic diseases have a lower ability to achieve  $VO_{2max}$  during a  
202 progressive test conducted until exhaustion<sup>20</sup>. However, in youths with obesity, current  
203 studies provide little data regarding the achievement of criteria for verifying  $VO_{2max}$ <sup>4-6</sup>.  
204 Therefore, knowledge about the individual's factors associated with the probability of  
205 achieving  $VO_{2max}$  remains limited. Although no statistically significant, the present  
206 results in a relatively large sample of youth with obesity (n=72) suggest that the grade  
207 of obesity may be associated with a lower probability of meet an  $HR > 95\% HR_{max}$  and a  
208 higher probability of meet a “hard” level of RPE. Thus, youths with higher grades of  
209 obesity might perceive the test as more difficult. This result may be of significance  
210 since perceptual responses play a major role during a progressive test conducted until  
211 exhaustion<sup>20</sup>. The present data would be supporting those of our predecessors<sup>5</sup> who  
212 found that RPE was higher in grade II than grade I obesity at the end of a treadmill test.  
213 They hypothesized that these differences could be due to an increased aerobic energy  
214 cost, a greater  $CO_2$  turnover, and a lower anaerobic threshold in grade II obesity. In the  
215 present study, the peak in minute ventilation normalized by body mass was significantly  
216 lower in youths with grade II than grade I obesity, and this differences persisted even  
217 after removing differences in body composition. This could mean that ventilatory  
218 adaptations to exercise were lower in grade II vs. grade I. Interestingly, it has been  
219 previsously suggested that lower cardiorespiratory fitness in youths with obesity could be  
220 partly explained by ventilatory factors<sup>21</sup>. The excess adipose tissue at the thoracic level  
221 would constrain them to breathe at low lung volumes, increasing the work of respiratory

222 muscles to the detriment of locomotor muscles<sup>21</sup>. Nevertheless, ventilatory factors  
223 would have a little impact on cardiorespiratory fitness in youths<sup>21</sup>. Accordingly, no  
224 differences were found between grade I and grade II regarding  $VO_{2peak}$  after removing  
225 differences in body mass and composition. Therefore, the present data would be in  
226 accordance with the previous hypothesis<sup>5</sup> that ventilatory factors are involved in the  
227 higher feeling of difficulty of youths with grade II obesity, but has limited influence on  
228  $VO_{2peak}$ <sup>21</sup>. Otherwise, breathing difficulties could also explain that youths with grade II  
229 obesity were less likely to met an  $HR > 95\% HR_{max}$ . It should be noted however that the  
230 relative HR at which the RPE was 5/10 ("hard") was higher than what could be  
231 expected, supporting previous data showing that RPE is underestimated in youths with  
232 obesity<sup>5,22,23</sup>.

233 Other factors may explain that youths with higher grades of obesity perceive their effort  
234 as more difficult. Firstly, obesity has many deleterious consequences on the  
235 musculoskeletal function of the lower limbs in youths<sup>24</sup>. Thus, lower limb pain  
236 sensations may contribute to the higher RPE in those who have obesity. Considering the  
237 low RPE scores found at the end of an incremental running or walking fitness test<sup>5,21,22</sup>,  
238 it could be relevant to use an RPE scale based on muscular sensations. Indeed, current  
239 RPE scales are based on cardiorespiratory sensations<sup>25</sup>, assuming that cardiorespiratory  
240 function is the limiting factor during an aerobic fitness test. Conversely, the  
241 combination of both a "local" and "overall" RPE scale would make it possible to  
242 dissociate the chest sensations from the lower limb sensations, which could help  
243 clinicians to better identify the reason for stopping the test. This approach has already  
244 been used in healthy children using an incremental cycling test and showed that "leg  
245 RPE" was significantly higher than "overall RPE" and "chest RPE".<sup>26</sup> Secondly, the  
246 lack of experience in vigorous-intensity exercises (due to poor engagement in physical

247 activities) is known to negatively affect RPE measurements<sup>27</sup>. However, physical  
248 activity levels were not measured in this study, limiting further interpretation of current  
249 data.

250 The probability of achieving  $VO_{2max}$  using a treadmill protocol according to the grade of  
251 obesity has previously been studied in women<sup>19</sup>. In accordance with the present results  
252 in youths, the authors found no differences between grade I and grade II obesity women  
253 regarding the achievement of a  $VO_2$  plateau. However, they also reported no differences  
254 regarding the achievement of secondary threshold criteria (i.e.,  $HR > 95\%HR_{max}$ ,  
255  $RER > 1.15$ ,  $RPE > 18/20$ , and blood lactate  $> 8 \text{ mmol.L}^{-1}$ ), contrary to the present study.  
256 Therefore, the lower ability of grade II obesity individuals to meet an  $HR > 95\%HR_{max}$   
257 during a treadmill test could only concern youths. According to a recent study<sup>28</sup>,  
258 treadmill tests would elicit ~4% lower  $HR_{peak}$  than active games in children with  
259 obesity. This study reinforces the idea that a high proportion of youths with obesity is  
260 not achieving a maximal effort during a treadmill test.

261 The  $VO_2$  plateau used to be the primary criteria for verifying  $VO_{2max}$ , but it is still  
262 debated whether the occurrence of  $VO_2$  plateau is only influenced by the sampling  
263 intervals, or if physiological factors could be involved<sup>29-31</sup>. In adults with obesity<sup>19</sup>, the  
264  $VO_2$  plateau was reached by 46% of the participants, which is higher than the 37%  
265 found in our study using the same definition of a  $VO_2$  plateau, but close to previous  
266 studies in youths with<sup>6</sup> or without<sup>32</sup> obesity. Since the range of  $VO_2$  plateau can vary  
267 from 30 to 50% between the studies<sup>6,32-33</sup>, the present differences are probably not  
268 meaningful. Furthermore, comparisons between studies might be not available since a  
269 different sampling interval<sup>29</sup> can significantly affect the results regarding the  $VO_2$   
270 plateau.

271

272 ***Limitations and perspectives***

273 This study has limitations. Although the methodology was based on the most recent  
274 recommendations<sup>18,34</sup>, the criteria that should be used to verify  $VO_{2max}$  are still debated.  
275 However, the use of supramaximal tests to verify the achievement of  $VO_{2max}$  is not  
276 clinically appropriate in youths with obesity. Furthermore, the present results could  
277 have been strengthened by physical activity data and the use of an RPE scale based on  
278 the muscular feeling of pain. These data could have strengthened the interpretation of  
279 the results regarding the mechanisms associated with the achievement of a  $VO_2$  plateau  
280 or secondary threshold criteria for verifying  $VO_{2max}$ . Despite these limitations, the  
281 present findings are of clinical importance since performing a maximal  
282 cardiorespiratory effort is the gold standard for measuring  $VO_{2max}$ <sup>3</sup>. According to the  
283 criteria used in this study and those of predecessors<sup>4-6</sup>, a high proportion of youths with  
284 different grades of obesity (approximating 50% in our study) would not  $VO_{2max}$  using a  
285 treadmill walking test. Thus, clinicians should be aware that  $VO_{2max}$  may be  
286 underestimated in this population when it is measured using these protocols.

287 **Conclusion**

288 The rate of achievement of an  $HR > 95\% HR_{max}$  and  $RPE > 5/10$  (“hard”) was respectively  
289 independent of the grade of obesity in a sample of 72 youths. These criteria were  
290 achieved by a minority of participants (15 to 64%), suggesting that a maximal  
291 cardiorespiratory effort was not achieved by the participants during the test. Youths  
292 with grade II obesity displayed a lower peak in minute ventilation normalized to fat-free  
293 mass and a premature feeling of difficulty than grade I during progressive walk tests,  
294 which may be attributable to higher ventilatory constraints and premature feeling of leg

295 muscular pain. Thus, our study supports the idea that a dose-response relationship exists  
296 between the grade of obesity and the psychophysiological responses to an incremental  
297 treadmill test in children.

298

299 **References**

- 300 1. Barry VW, Caputo JL, Kang M. The Joint Association of Fitness and Fatness on  
301 Cardiovascular Disease Mortality: A Meta-Analysis. *Prog Cardiovasc Dis.*  
302 2018;61(2):136-141. DOI:10.1016/j.pcad.2018.07.004
- 303 2. Imboden MT, Kaminsky LA, Peterman JE, et al. Cardiorespiratory Fitness  
304 Normalized to Fat-Free Mass and Mortality Risk. *Med Sci Sports Exerc.*  
305 2020;52(7):1532-1537. DOI:10.1249/MSS.0000000000002289
- 306 3. Poole DC, Richardson RS. Determinants of oxygen uptake. Implications for  
307 exercise testing. *Sports Med.* 1997;24(5):308-320. DOI:10.2165/00007256-  
308 199724050-00003
- 309 4. Gutin B, Barbeau P, Owens S, et al. Effects of exercise intensity on  
310 cardiovascular fitness, total body composition, and visceral adiposity of obese  
311 adolescents. *Am J Clin Nutr.* 2002;75(5):818-826. DOI:10.1093/ajcn/75.5.818
- 312 5. Marinov B, Kostianev S, Turnovska T. Ventilatory efficiency and rate of  
313 perceived exertion in obese and non-obese children performing standardized  
314 exercise. *Clin Physiol Funct Imaging.* 2002;22(4):254-260. DOI:10.1046/j.1475-  
315 097x.2002.00427.x
- 316 6. Breithaupt PG, Colley RC, Adamo KB. Using the oxygen uptake efficiency  
317 slope as an indicator of cardiorespiratory fitness in the obese pediatric  
318 population. *Pediatr Exerc Sci.* 2012;24(3):357-368. DOI:10.1123/pes.24.3.357

- 319 7. Peyrot N, Thivel D, Isacco L, Morin JB, Belli A, Duche P. Why does walking  
320 economy improve after weight loss in obese adolescents?. *Med Sci Sports*  
321 *Exerc.* 2012;44(4):659-665. DOI:10.1249/MSS.0b013e318236edd8
- 322 8. Thivel D, Masurier J, Baquet G, et al. High-intensity interval training in  
323 overweight and obese children and adolescents: systematic review and meta-  
324 analysis. *J Sports Med Phys Fitness.* 2019;59(2):310-324. DOI:10.23736/S0022-  
325 4707.18.08075-1
- 326 9. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs  
327 for thinness, overweight and obesity. *Pediatr Obes.* 2012;7(4):284-294.  
328 DOI:10.1111/j.2047-6310.2012.00064.x
- 329 10. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J.  
330 Development of a WHO growth reference for school-aged children and  
331 adolescents. *Bull World Health Organ.* 2007;85(9):660-667.  
332 DOI:10.2471/blt.07.043497
- 333 11. Mirwald RL, Baxter-Jones AD, Bailey DA, Beunen GP. An assessment of  
334 maturity from anthropometric measurements. *Med Sci Sports Exerc.*  
335 2002;34(4):689-694. DOI:10.1097/00005768-200204000-00020
- 336 12. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited.  
337 *J Am Coll Cardiol.* 2001;37(1):153-156. DOI:10.1016/s0735-1097(00)01054-8
- 338 13. Midgley AW, McNaughton LR, Polman R, Marchant D. Criteria for  
339 determination of maximal oxygen uptake: a brief critique and recommendations  
340 for future research. *Sports Med.* 2007;37(12):1019-1028.  
341 DOI:10.2165/00007256-200737120-00002
- 342 14. Midgley AW, Bentley DJ, Luttikholt H, McNaughton LR, Millet GP.  
343 Challenging a dogma of exercise physiology: does an incremental exercise test



- 344 for valid  $\text{VO}_2$  max determination really need to last between 8 and 12 minutes?.
- 345 Sports Med. 2008;38(6):441-447. DOI:10.2165/00007256-200838060-00001
- 346 15. Hermand E, Cassirame J, Ennequin G, Hue O. Validation of a
- 347 Photoplethysmographic Heart Rate Monitor: Polar OH1. Int J Sports Med.
- 348 2019;40(7):462-467. DOI:10.1055/a-0875-4033
- 349 16. Blanchard J, Blais S, Chetaille P, et al. Determination of peak cardiorespiratory
- 350 fitness parameters in children: which averaging method should we use?. J Sports
- 351 Sci. 2019;37(11):1265-1269. DOI:10.1080/02640414.2018.1554976
- 352 17. Williams JG, Eston R, Furlong B. CERT: a perceived exertion scale for young
- 353 children. Percept Mot Skills. 1994;79(3 Pt 2):1451-1458.
- 354 DOI:10.2466/pms.1994.79.3f.1451
- 355 18. Niemeyer M, Bergmann TGJ, Beneke R. Oxygen uptake plateau: calculation
- 356 artifact or physiological reality?. Eur J Appl Physiol. 2020;120(1):231-242.
- 357 DOI:10.1007/s00421-019-04267-7
- 358 19. Wood RE, Hills AP, Hunter GR, King NA, Byrne NM.  $\text{VO}_{2\text{max}}$  in overweight
- 359 and obese adults: do they meet the threshold criteria?. Med Sci Sports Exerc.
- 360 2010;42(3):470-477. DOI:10.1249/MSS.0b013e3181b666ad
- 361 20. Poole DC, Jones AM. Measurement of the maximum oxygen uptake  $\dot{\text{V}}\text{O}_{2\text{max}}$ :
- 362  $\dot{\text{V}}\text{O}_{2\text{peak}}$  is no longer acceptable. J Appl Physiol (1985). 2017;122(4):997-1002.
- 363 DOI:10.1152/jappphysiol.01063.2016
- 364 21. Mendelson M, Michallet AS, Tonini J, Favre-Juvin A, Guinot M, Wuyam B,
- 365 Flore P. Low Cardiorespiratory Fitness is Partially Linked to Ventilatory Factors
- 366 in Obese Adolescents. Pediatr Exerc Sci. 2016 Feb;28(1):87-97. doi:
- 367 10.1123/pes.2013-0151. Epub 2015 Aug 25. PMID: 26305371.

- 368 22. Thivel D, Isacco L, O'Malley G, Duché P. Pediatric Obesity and Perceived  
369 Exertion: Difference Between Weight-Bearing and Non-Weight-Bearing  
370 Exercises Performed at Different Intensities. *J Sports Sci.* 2016;34(5):389-394.  
371 DOI:10.1080/02640414.2015.1061200
- 372 23. Thivel D, O'Malley G, Blourdier D, Tremeaux M, Zanchet C, Pereira B, Ratel S.  
373 Reproducibility of the intermittent Spartacus Run Test in obese adolescents. *J*  
374 *Sports Med Phys Fitness.* 2017 Sep;57(9):1083-1088. doi: 10.23736/S0022-  
375 4707.16.06534-8. Epub 2016 Jul 7. PMID: 27387496.
- 376 24. O'Malley G, Hussey J, Roche E. A pilot study to profile the lower limb  
377 musculoskeletal health in children with obesity. *Pediatr Phys Ther.*  
378 2012;24(3):292-298. DOI:10.1097/PEP.0b013e31825c14f8
- 379 25. Quinart S, Gros Lambert A, Ecartot F, Simon-Rigaud ML, Nicolet-Guénat M,  
380 Nègre V, Mouglin F. Validation of a new scale to measure perceived exertion in  
381 obese adolescents: the Childhood Obesity Perceived Exertion (Cope-10) Scale. *J*  
382 *Sports Med Phys Fitness.* 2016 Sep;56(9):1013-20. Epub 2015 Jul 1. PMID:  
383 26129916.
- 384 26. Robertson RJ, Goss FL, Boer NF, Peoples JA, Foreman AJ, Dabayeb IM,  
385 Millich NB, Balasekaran G, Riechman SE, Gallagher JD, Thompkins T.  
386 Children's OMNI scale of perceived exertion: mixed gender and race validation.  
387 *Med Sci Sports Exerc.* 2000 Feb;32(2):452-8. doi: 10.1097/00005768-  
388 200002000-00029. PMID: 10694131.
- 389 27. Belanger K, Breithaupt P, Ferraro ZM, Barrowman N, Rutherford J,  
390 Hadjiyannakis S, Colley RC, Adamo KB. Do obese children perceive  
391 submaximal and maximal exertion differently? *Clin Med Insights Pediatr.* 2013

- 392 Sep 8;7:35-40. doi: 10.4137/CMPed.S12524. PMID: 24052695; PMCID:  
393 PMC3775604.
- 394 28. Berntsen S, Edvardsen E, Gerbi S, Kolsgaard ML, Anderssen SA. Do Obese  
395 Children Achieve Maximal Heart Rate during Treadmill Running? Sports  
396 (Basel). 2019 Jan 19;7(1):26. doi: 10.3390/sports7010026. PMID: 30669424;  
397 PMCID: PMC6359420.
- 398 29. Astorino TA. Alterations in V<sub>O</sub>max and the V<sub>O</sub> plateau with manipulation of  
399 sampling interval. Clin Physiol Funct Imaging. 2009 Jan;29(1):60-7. doi:  
400 10.1111/j.1475-097X.2008.00835.x. PMID: 19125732.
- 401 30. Beltrami FG, Wong del P, Noakes TD. High prevalence of false-positive plateau  
402 phenomena during VO<sub>2max</sub> testing in adolescents. J Sci Med Sport. 2014  
403 Sep;17(5):526-30. doi: 10.1016/j.jsams.2013.07.012. Epub 2013 Aug 8. PMID:  
404 23992661.
- 405 31. Niemeyer M, Bergmann TGJ, Beneke R. Oxygen uptake plateau: calculation  
406 artifact or physiological reality? Eur J Appl Physiol. 2020 Jan;120(1):231-242.  
407 doi: 10.1007/s00421-019-04267-7. Epub 2019 Nov 20. PMID: 31748882.
- 408 32. Sansum KM, Weston ME, Bond B, Cockcroft EJ, O'Connor A, Tomlinson OW,  
409 Williams CA, Barker AR. Validity of the Supramaximal Test to Verify Maximal  
410 Oxygen Uptake in Children and Adolescents. Pediatr Exerc Sci. 2019 May  
411 1;31(2):213-222. doi: 10.1123/pes.2018-0129. Epub 2019 Mar 18. PMID:  
412 30885084.z

413 33. Rowland TW, Cunningham LN. Oxygen uptake plateau during maximal  
414 treadmill exercise in children. *Chest*. 1992 Feb;101(2):485-9. doi:  
415 10.1378/chest.101.2.485. PMID: 1735277.

416 34. Marinus N, Bervoets L, Massa G, et al. Altered gas-exchange at peak exercise in  
417 obese adolescents: implications for verification of effort during cardiopulmonary  
418 exercise testing. *J Sports Med Phys Fitness*. 2017;57(12):1687-1694.  
419 DOI:10.23736/S0022-4707.16.06607-X

420

421 Table 1 : Participants' characteristics, cardiorespiratory and perceptual responses by  
 422 grade of obesity subgroups.

	IOTF Grade I obesity (n=15)	IOTF Grade II obesity (n=57)
Age (years)	11.9 ± 1.8	11.6 ± 1.8
Age of PHV (years)	12.8 ± 1.2	12.0 ± 0.9*
Maturity (years from PHV)	-0.9 ± 1.1	-0.4 ± 1.8
Height (cm)	152 ± 10	153 ± 11
Weight (kg)	56.0 ± 11.7	70 ± 18.8***
Body Mass Index (kg.m <sup>-2</sup> )	23.9 ± 2.2	29.8 ± 4.6***
Fat mass (% body mass)	28.7 ± 4.4	39.1 ± 7.1***
IOTF BMI z-score (SD)	1.8 ± 0.2	2.7 ± 0.5***
VE <sub>peak</sub> mL.kgFFM <sup>-1</sup> .min <sup>-1</sup>	1.94 ± 0.33	1.71 ± 0.31*
VE <sub>peak</sub> mL.kgBM <sup>-1</sup> .min <sup>-1</sup>	1.39 ± 0.26	1.04 ± 0.24***
VO <sub>2peakBM</sub> (mL.kgBM <sup>-1</sup> .min <sup>-1</sup> )	34.5 ± 7.1	27.2 ± 5.1**
VO <sub>2peakFFM</sub> (mL.kgFFM <sup>-1</sup> .min <sup>-1</sup> )	48.2 ± 8.7	44.8 ± 7.4
HR <sub>peak</sub> (bpm)	192 ± 14	185 ± 13
HR <sub>peak</sub> (% predicted HR <sub>max</sub> )	96.2 ± 7.1	92.5 ± 6.7
HR <sub>RPEhard</sub> (%HR <sub>peak</sub> )	93.3 ± 6.2	94.1 ± 4.7
RER <sub>peak</sub> (Arbitrary unit)	1.10 ± 0.17	1.08 ± 0.14

423

424 Table 2 : Number and rate of participants having reached the criteria for verifying VO<sub>2max</sub>  
 425 and achieved VO<sub>2max</sub> according to these criteria, by grade of obesity and results of  
 426 logistic regressions.

	VO <sub>2max</sub>		VO <sub>2</sub> plateau		HR>95%		RER>1.0		RPE>5/10	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Grade I	n=7 47%	n=8 53%	n=4 27%	n=11 73%	n=9 60%	n=6 40%	n=8 53%	n=7 47%	n=12 80%	n=3 20%
Grade II	n=33 58%	n=24 42%	n=23 40%	n=34 60%	n=19 33%	n=38 67%	n=39 68%	n=18 32%	n=54 95%	n=3 5%
X <sup>2</sup> tests	<i>P</i> =0.44		<i>P</i> =0.33		<i>P</i> =0.06		<i>P</i> =0.27		<i>P</i> =0.07	
OR	NS		NS		0.33		NS		4.5	

427 Abbreviations : VO<sub>2</sub> = oxygen uptake ; HR = heart rate ; OR = odds-ratio; RER = respiratory exchange  
 428 ratio ; RPE = rating of perceived exertion ; X<sup>2</sup> = chi-square tests  
 429