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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 adults¹,
46 especially when it is normalized by fat-free mass². 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 exhaustion³. 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 obesity⁴⁻⁶. During these tests, the speed
51 is constant and usually between 3.5 and 5 km.h⁻¹, which is close to the preferred
52 walking speed in this population⁷. The intensity is increased by increasing the slope,
53 amounting to 1 or 2% per minute^{4,5}. 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} ⁴. Using the same protocol, a study⁶ 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 study⁵ did not specify the
61 criteria⁴ 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 obesity⁸,
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 85th percentile of the IOTF
79 standards for BMI, defining grade I obesity in youths⁹. 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 IOTF⁹ and
 99 WHO¹⁰ 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.¹¹ :

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

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

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

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

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

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 yet¹¹. 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⁻¹ 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 Tanaka¹² [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 participants¹³. 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⁻¹ for a starting speed between 3.0 km.h⁻¹ and 3.7 km.h⁻¹
121 or by 0.4 km.h⁻¹ for a starting speed between 3.7 and 4.5 km.h⁻¹. This protocol was
122 selected because high treadmill grades would be associated with an increased failure to
123 achieve VO_{2max}¹⁴. 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)¹⁵ positioned at the left wrist. The peak heart rate (HR_{peak})
128 observed during the test was the highest value averaged on 3 points. The VO₂ 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 youths¹⁶.
133 Rating of perceived exertion (RPE) was continuously assessed using the CR-10 Borg
134 scale previously used in youths with obesity⁵. 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 youths¹⁷.

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

142 Following previous studies in youths with obesity^{4,6}, 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 recommended¹⁸ and used to detect VO_2 plateaus in adults with obesity¹⁹. 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 exhaustion²⁰. However, in youths with obesity, current
203 studies provide little data regarding the achievement of criteria for verifying VO_{2max} ⁴⁻⁶.
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 exhaustion²⁰. The present data would be supporting those of our predecessors⁵ 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 factors²¹. 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 muscles²¹. Nevertheless, ventilatory factors
223 would have a little impact on cardiorespiratory fitness in youths²¹. 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 hypothesis⁵ 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} ²¹. 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^{5,22,23}.

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 youths²⁴. 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^{5,21,22},
238 it could be relevant to use an RPE scale based on muscular sensations. Indeed, current
239 RPE scales are based on cardiorespiratory sensations²⁵, 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".²⁶ Secondly, the
246 lack of experience in vigorous-intensity exercises (due to poor engagement in physical

247 activities) is known to negatively affect RPE measurements²⁷. 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 women¹⁹. 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 study²⁸,
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 involved²⁹⁻³¹. In adults with obesity¹⁹, 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 with⁶ or without³² obesity. Since the range of VO_2 plateau can vary
267 from 30 to 50% between the studies^{6,32-33}, the present differences are probably not
268 meaningful. Furthermore, comparisons between studies might be not available since a
269 different sampling interval²⁹ 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^{18,34}, 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} ³. According to the
283 criteria used in this study and those of predecessors⁴⁻⁶, 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 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, Mougín 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_Omax and the V_O 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_{2max} 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 ⁻²)	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 _{peak} mL.kgFFM ⁻¹ .min ⁻¹	1.94 ± 0.33	1.71 ± 0.31*
VE _{peak} mL.kgBM ⁻¹ .min ⁻¹	1.39 ± 0.26	1.04 ± 0.24***
VO _{2peakBM} (mL.kgBM ⁻¹ .min ⁻¹)	34.5 ± 7.1	27.2 ± 5.1**
VO _{2peakFFM} (mL.kgFFM ⁻¹ .min ⁻¹)	48.2 ± 8.7	44.8 ± 7.4
HR _{peak} (bpm)	192 ± 14	185 ± 13
HR _{peak} (% predicted HR _{max})	96.2 ± 7.1	92.5 ± 6.7
HR _{RPEhard} (%HR _{peak})	93.3 ± 6.2	94.1 ± 4.7
RER _{peak} (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_{2max}
 425 and achieved VO_{2max} according to these criteria, by grade of obesity and results of
 426 logistic regressions.

	VO _{2max}		VO ₂ 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 ² 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 : VO₂ = oxygen uptake ; HR = heart rate ; OR = odds-ratio; RER = respiratory exchange
 428 ratio ; RPE = rating of perceived exertion ; X² = chi-square tests
 429