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1   **The influence of a six week exercise intervention on the pulmonary oxygen uptake kinetics in**

2   **pre-pubertal obese and normal weight children**

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16

17   **Running title:** Influence of a 6 week intervention on $\dot{V}O_2$ kinetic

18

19   There are no conflicts of interest

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22

23 **Abstract**

24 Purpose: The pulmonary oxygen uptake ($\dot{V}O_2$) response is deleteriously influenced by obesity in pre-

25 pubertal children, as evidenced by a slower phase II response relative to their normal-weight

26 counterparts. To date, no studies have investigated the ability of an exercise intervention to ameliorate

27 this deleterious influence. Therefore, the purpose of the present study was to investigate the influence

28 of a six week, high-intensity games orientated intervention on the $\dot{V}O_2$ kinetic response of pre-

29 pubertal obese (OB) and normal-weight (NW) children during heavy intensity exercise.

30 Methods: Thirteen NW and fifteen OB children participated in a twice weekly exercise intervention

31 involving repeated bouts of 6-minutes of high-intensity, games-orientated exercises followed by 2

32 minutes of recovery. Sixteen NW and eleven OB children served as a control group. At baseline and

33 post-intervention, each participant completed a graded-exercise test to volitional exhaustion and

34 constant work rate heavy intensity exercise (40% of the difference between the gas exchange

35 threshold and peak $\dot{V}O_2$).

36 Results: Following the intervention, OB children demonstrated a significantly reduced phase II τ (Pre:

37 30±8 cf. Post: 24±7 s), MRT (Pre: 50±10 cf. Post: 38±9 s) and phase II amplitude (Pre: 1.51±0.30 cf.

38 Post: 1.34 ± 0.27). In contrast, the intervention did not elicit any changes in the dynamic $\dot{V}O_2$

39 response in NW children.

40 Conclusions: The present findings demonstrate that a six-week, high-intensity intervention can have a

41 significant positive impact on the dynamic $\dot{V}O_2$ response of obese pre-pubertal children.

42

43 **Keywords:** High intensity; games; $\dot{V}O_2$ kinetics; exercise intensity; training; BMI

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45

46

Introduction

48 The prevalence of childhood obesity has reached epidemic proportions (Watts et al. 2005), with the

49 World Health Organisation (WHO) recognising it as a major public health challenge of the 21st

50 century (WHO 2010). This is of paramount importance considering that obesity is strongly associated

51 with the occurrence of comorbities such as insulin resistance, type II diabetes mellitus, coronary

52 artery disease, stroke and heart failure (Poirier et al. 2006). Recent statistics suggest that ~30% of

53 children are overweight or obese (Townsend et al. 2013). Furthermore, childhood obesity is known to

54 track strongly into adolescence and adulthood, with evidence suggesting that 80% of obese

55 adolescents will become obese adults (Schonfeld-Warden et al. 1997). Exercise has been widely

56 recognised as pivotal to resolving this obesity epidemic, however, there is little agreement within the

57 literature as to effective exercise interventions. Regular physical activity and exercise participation for

58 children, therefore, may be important in attenuating or even alleviating the severity of childhood

59 obesity.

60 Pulmonary oxygen uptake ($\dot{V}O_2$) kinetics describe the finite rate of adjustment to a sudden change in

61 metabolic demand, thus providing a functional evaluation of the integration of the pulmonary,

62 cardiovascular and skeletal systems (Whipp et al. 1990). During moderate intensity exercise below the

63 gas exchange threshold (GET), $\dot{V}O_2$ rises in a near-exponential manner (the so-called phase II

64 response), attaining a steady-state within 2-3 minutes in young, healthy adults (Whipp et al. 1972;

65 Whipp et al. 1982). The dynamic $\dot{V}O_2$ response becomes appreciably more complex during exercise

66 above the GET, with attainment of a steady state delayed, or even precluded, by the presence of a

67 supplementary "slow component" of $\dot{V}O_2$ (Whipp and Wasserman 1972; Barstow et al. 1991), that is

68 thought to originate in the exercising muscle (Poole et al. 1991; Jones et al. 2011). This $\dot{V}O_2$ response

69 has been shown to be highly sensitive in children, for example, a higher cardiorespiratory fitness is

70 associated with a faster phase II time constant (τ) (McNarry et al. 2010; Winlove et al. 2010).

71 Conversely, $\dot{V}O_2$ kinetics have also been shown to be deleteriously influenced by obesity during

72   weight-bearing exercise (Lambrick et al. 2013). The findings of this latter study are particularly

73   pertinent given the utilisation of a weight-bearing exercise (i.e., walking, running) which is an

74   important part of the daily activities of children. However, despite the sensitivity of $\dot{V}O_2$ kinetics and

75   the pivotal role of exercise and physical activity as an intervention to resolve obesity, no study to date

76   has investigated the influence of an exercise intervention on the $\dot{V}O_2$ response. Rather the reliance on

77   peak $\dot{V}O_2$ as an indicator of aerobic fitness, despite the common recognition that this parameter can

78   lack sensitivity (Impellizzeri et al. 2005; Meyer et al. 2005), may explain, at least in part, the

79   discrepancy in the literature with regard to the trainability of pre-pubertal children (e.g. Welsman et

80   al. 1997; Obert et al. 2009; Rowland et al. 2009). The importance of using appropriate modalities and

81   parameters to assess the influence of training and interventions is especially evident in paediatric

82   populations, particularly when considering that a meta-analysis demonstrated that aerobic endurance

83   training may only elicit a 5-6% increase in peak $\dot{V}O_2$ (Baquet et al. 2003). The equivocal findings of

84   previous studies may also be attributable to differences in the duration, intensity and/or type of

85   exercise programme. Whilst the majority of previous studies have utilised continuous, sustained bouts

86   of exercise, such bouts fail to reflect the highly sporadic nature of children's play patterns which are

87   characterised by bursts of high-intensity, intermittent exercise (Bailey et al. 1995).

88

89   Therefore, the purpose of the present study was to investigate the effect of a short-term exercise

90   intervention on the pulmonary oxygen uptake response of obese and normal weight children. To

91   ensure participant adherence and the relevance of the intervention to the daily physical activity

92   patterns of children, a high-intensity games model was used. We hypothesised that the intervention

93   would significantly speed the $\dot{V}O_2$ kinetics in the obese children. Furthermore, we also hypothesised

94   that the intervention would not influence the $\dot{V}O_2$ kinetics of the normal weight children due to their

95   assumed higher baseline aerobic fitness.

96

97   **Methods**

98   *Participants*

99   Twenty-six obese (OB) children (9.3±0.9 y, 143.5±8.8 cm, 48.9±10.6 kg, 23.5±3.6 kg·m^2, 13 boys)

100   and twenty-nine healthy normal weight (NW) children (9.2±0.8 y, 137.5±8.8 cm, 32.2±5.6 kg,

101   16.9±1.6 kg·m^2, 17 boys) volunteered for this study. BMI percentiles were used to classify children as

102   either NW (5th to 85th percentile) or OB (≥ 95th percentile) (Cole et al. 2012). The participants were

103   pre-pubescent, as determined by their predicted age at peak height velocity (Mirwald et al. 2002). On

104   average, children took part in two or more weekly bouts of physical activity (i.e., football, netball,

105   bike riding), as determined by parental-reports of activity status. Reported physical activity did not

106   differ between the obese and normal weight children. Child assent and parent/guardian consent were

107   obtained prior to participation. This research was conducted in agreement with the guidelines and

108   policies of the institutional ethics committee.

109

110   *Procedure*

111   Participants took part in four laboratory-based exercise sessions; two maximal graded-exercise tests

112   (GXT) to peak oxygen consumption ($\dot{V}O_2$ peak) and two repeated constant work rate exercise tests, all

113   of which were conducted on a treadmill (True 825, Fitness Technologies, St Louis, USA).

114

115   Standing- and seated height (measured to the nearest 0.1cm; SECA, Hamburg, Germany), body

116   weight, fat-free mass (measured to the nearest 0.1kg) and body fat percentage (% BF; measured with

117   bioelectrical impedance analysis: InBody Biospace 230, Los Angeles, USA) were obtained on the

118   initial visit to the laboratory. Following this, participants completed a baseline GXT to $\dot{V}O_2$ peak.

119   After a minimum 72 hour interim period, participants completed a baseline constant work-rate

120   exercise test. OB and NW participants were then randomised to either a 6-week child-specific, high-

121   intensity exercise intervention, completed during school hours, or to a usual care control group which

122   incorporated normal classroom activities. On completion of the exercise programme, all participants

123   completed a post-intervention GXT to $\dot{V}O_2$peak and constant work-rate exercise test, similar to

124   baseline.

125

126   Throughout all exercise tests, the treadmill grade was set at 1%. On-line respiratory gas analysis was

127   undertaken continuously using a breath-by-breath automatic gas exchange system (Sensormedics

128   Corporation, Yorba Linda, CA, USA). Children wore a paediatric facemask while they exercised to

129   allow respiratory variables to be monitored continuously. A paediatric wireless chest strap telemetry

130   system (Polar Electro T31, Kempele, Finland) measured heart rate (HR) throughout each exercise test.

131   All physical and physiological data were concealed from the participants for the duration of each test.

132

133   *Graded exercise test*

134   Children were firstly familiarised to a range of treadmill speeds (4, 6 & 8 $km \cdot h^{-1}$) and the testing

135   equipment. Habituation to the apparatus was considered essential to reduce any potential bias in the

136   measurements. The GXT followed a discontinuous incremental protocol to ascertain peak oxygen

137   uptake ($\dot{V}O_2$) and maximal HR (HRmax) (Lambrick et al. 2011; Lambrick, Faulkner et al. 2013).

138   During this test participants completed a series of 1 minute exercise bouts with 1-minute recovery

139   periods interspersed between each active bout of exercise until participants reported volitional

140   exhaustion (For more details, see Lambrick, Faulkner et al. 2013) . The $\dot{V}O_2$peak was taken as the

141   highest 10-s average value attained in the test. The GET was determined by the V-slope method

142   (Beaver et al. 1986). Using the $\dot{V}O_2$ values reported at GET and $\dot{V}O_2$peak, the running speeds

143   equivalent to 90 % GET (moderate exercise) and 40% delta (difference between GET and $\dot{V}O_2$peak;

144   heavy exercise) were calculated for the constant work rate tests with the mean response time (MRT)

145   for $\dot{V}O_2$ during ramp exercise accounted for (i.e., two-thirds of the ramp rate was deducted from the

146   work rate at the GET and $\dot{V}O_2$peak (Whipp et al. 1981).

147

148   *Constant work rate tests*

149   For the determination of $\dot{V}O_2$ kinetics, participants completed a series of "step" tests. The protocol

150   required participants to complete one moderate and one heavy intensity exercise bout, each of 6 min

151   duration. Each bout was preceded by 5 min of rest followed by an abrupt transition to the target speed.

152

153 *Randomisation*

154 Participants were randomised to either a 6-week exercise programme (EX) or to a usual care control

155 group (CON). OB and NW participants were randomly assigned using simple randomisation

156 procedures (computerised random numbers). However, to ensure equal distribution of OB and NW

157 children to both EX and CON the randomisation procedure was implemented separately for each

158 group (OB, NW). Details of the allocated group were given on a piece of paper contained within

159 sequentially numbered, opaque sealed envelopes. The randomisation procedures were prepared by an

160 investigator with no involvement in the trial. Following randomisation, there were no significant

161 differences between the exercise and control groups with regard to their anthropometrics, peak or

162 constant work rate responses.

163

164 *Exercise intervention*

165 Participants randomised to EX completed a supervised high-intensity, child-specific, discontinuous

166 games programme for 6 weeks. This included participation in twice weekly 60 minute exercise

167 sessions, during which children were physically active for 40 minutes. There was a minimum 48 hour

168 recovery period between sessions. These sessions were conducted outside of the children's normal

169 Physical Education lessons (1 hr·wk^{-1}) and were therefore considered supplementary exercise.

170

171 A two week pilot study demonstrated that children could manage repeated bouts of 6-minutes of high-

172 intensity exercise followed by 2 minutes of recovery. To increase motivation, enjoyment and

173 adherence, and to ensure children took part in each game at a high-intensity, different games (n=14)

174 were used for each 6-minute exercise period (Howe et al. 2010). The 2-minute recovery period

175 allowed researchers to provide instructions concerning the subsequent game activity. During each

176 session, children took part in 6 child-specific games and a 4-minute circuit which included ladder

177 running, step-ups, skipping, star jumps, high knees, shuttle runs, jumping jacks and lateral jumps. HR

178 was constantly monitored throughout each exercise session (Polar Team^2 system, POLAR, Oulu,

179 Finland).

180

181 The CON group continued to attend their weekly Physical Education classes, but no additional

182 exercise sessions were implemented.

183

184 *Data analysis*

185 The $\dot{V}O_2$peak from the GXT is reported in absolute (L·min⁻¹) and relative terms (mL·kg⁻¹·min⁻¹;

186 mL·kg^LBM·min⁻¹[where LBM is $\dot{V}O_2$peak expressed relative to lean body mass]). Furthermore, the

187 influence of body size was accounted for using analysis of covariance (ANCOVA) on log transformed

188 data to determine the allometric relationship between body mass and peak $\dot{V}O_2$. Common allometric

189 exponents were confirmed for all groups and power function ratios (Y/X^b) were computed.

190

191 Initially, the breath-by-breath $\dot{V}O_2$ responses to each step transition were visually examined to

192 remove any errant breaths caused by coughing, swallowing, sighing, etc., using a 5-s moving average

193 to identify points lying in excess of 4 standard deviations from the local mean. Subsequently, each

194 transition was interpolated to 1-s intervals, time aligned to the start of exercise and averaged. To

195 remove the influence of the cardiodynamic phase on the analysis of the subsequent response, the first

196 20s of data were ignored. Subsequently, following baseline correction, a mono-exponential model

197 with a time delay (Eq.1) was then applied to this averaged response:

198

199 $$\dot{V}O_{2(t)} = A_1 \cdot (1 - e^{-(t-\delta_1)/\tau_1}) \qquad\qquad \text{(Eq. 1)}$$

200

201 where $\Delta\dot{V}O_2$ is the increase in $\dot{V}O_2$ at time t above the baseline value (calculated as the mean $\dot{V}O_2$

202 from the first 45-s of the last min of baseline), and A_1, δ_1 and τ_1 are the primary component amplitude,

203 time delay (which was allowed to vary freely), and time constant, respectively. Kinetic variables (A_1,

204 δ_1 and τ_1) and their 95% confidence intervals were determined by least squares non-linear regression

205 analysis (Graphpad Prism, Graphpad Software, San Diego, CA). A mono-exponential model was

206 ultimately used for both moderate and heavy intensity exercise as a bi-exponential ($\Delta\dot{V}O_{2(t)} = A_1 \cdot$

207    $(1 - e^{-(t-\delta_1)/\tau_1}) + A_2 \cdot (1 - e^{-(t-\delta_2)/\tau_2}))$ during heavy exercise was found to produce an inferior

208   and ambiguous fit.

209

210   Given the failure of the bi-exponential model to describe the $\dot{V}O_2$ response during heavy intensity

211   exercise, the onset of the $\dot{V}O_2$ slow component was determined using purpose designed LabVIEW

212   software which iteratively fits a monoexponential function to the $\dot{V}O_2$ data until the window

213   encompasses the entire response. The resulting phase II time constants were plotted against time and

214   the onset of the $\dot{V}O_2$ slow component identified as the point at which the phase II time constant

215   consistently deviates from the previously "flat" profile. The amplitude of the $\dot{V}O_2$ peak slow

216   component was subsequently determined by calculating the difference between the end exercise $\dot{V}O_2$

217   and the sum of the primary amplitude and baseline $\dot{V}O_2$. This was expressed both in absolute terms

218   and relative to end exercise $\dot{V}O_2$. The functional gain of the phase II $\dot{V}O_2$ response during both

219   exercise intensities was also calculated by dividing the primary phase amplitude by the change in

220   speed. The mean response time (MRT) was calculated by fitting a single exponential curve to the data

221   with no time delay from the onset of exercise to the end of exercise. Finally, the oxygen deficit was

222   determined using the MRT (expressed as a fraction of a minute) and the phase II amplitude.

223

224   Gaussian distribution was confirmed by the Shapiro-Wilks test. The influence of gender was assessed

225   by an independent sample t-test which revealed no differences during either the incremental or

226   constant work rate tests. Therefore, the data for boys and girls were pooled for all further analyses. A

227   series of three-factor repeated measures analysis of variance (ANOVA),   with weight status (NW,

228   OB) and exercise condition (EX, CON) as the between-participant factors and test (baseline, post-

229   intervention) as the within-participant factor, were used to analyse maximal data from the GXT to $\dot{V}$

230   O_2peak and the physiological data reported from the constant work rate tests (for both moderate &

231   heavy intensity exercise). Where statistical differences were observed, post-hoc analyses using

232   Tukey's HSD were performed to identify where these differences lay. Where applicable, intention-to-

233   treat analysis, whereby individual data recorded from the baseline assessment from a single

234 participant was carried forward and used in place of any missing data from the post-intervention

235 assessment, was used on all relevant repeated-measures statistical procedures. All statistical analyses

236 were conducted using PASW Statistics 21 (SPSS, Chicago, IL). All data are presented as means ± SD.

237 Statistical significance was accepted when $P \leq 0.05$.

238

239 **Results**

240 *Descriptive statistics*

241 Participant descriptives are summarised in Table 1. There were no anthropometrical differences

242 following randomisation between the exercise and control groups. The obese children demonstrated a

243 significantly higher weight (OB, 49.2 ± 8.9 cf. NW, 32.5 ± 8.9 kg; $P < 0.05$), BMI (OB, 23.3 ± 2.9 cf.

244 NW, 17.0 ± 2.9 kg·m^{-2}; $P < 0.05$) and %BF (OB, 32.3 ± 7.0 cf. NW, 20.7 ± 6.9%; $P < 0.05$) than their

245 normal weight counterparts throughout the entire study. Irrespective of weight status, body mass

246 increased from baseline to post-intervention (40.4 ± 8.6 cf. 41.4 ± 9.3 kg, respectively; $P < 0.05$)

247

248 *Maximal physiological responses*

249 The physiological responses to the incremental exercise test are summarised in Table 2. Both at

250 baseline and post-intervention, OB children demonstrated a higher $\dot{V}O_2$peak than NW children when

251 expressed in absolute terms (2.4 ± 0.4 cf. 2.0 ± 0.4 L·min^{-1}, respectively; $P < .001$), but no differences

252 were observed when allometrically expressed relative to body mass. A significant increase in absolute

253 $\dot{V}O_2$ peak was observed between baseline and post-intervention (2.1 ± 0.4 cf. 2.2 ± 0.4 L·min^{-1},

254 respectively; $P < .001$), but relative peak $\dot{V}O_2$, was unchanged. Furthermore, there were no main

255 effects or interactions for HR (all $P > .05$), GET (L·min^{-1}) or the fraction of VO_2peak at which the

256 GET occurred, irrespective of weight status (OB, NW) or exercise condition (EX, CON) ($P > .05$).

257

258   *VO₂ kinetics: Moderate intensity exercise*

259   During the moderate intensity exercise (Table 3), a trend was observed for a Test by Exercise

260   Condition interaction for the phase II amplitude (P=0.061). Follow-up analysis demonstrated a lower

261   phase II amplitude at the post-intervention than baseline assessment for EX (0.44±0.09 cf. 0.47±0.09

262   L·min^{-1}, respectively) but not for CON (0.46±0.09 cf. 0.45±0.09 L·min^{-1}, respectively). The phase II

263   amplitude and gain were significantly higher in the OB children (all P<.01).

264   *VO₂ kinetics: Heavy intensity exercise*

265   The physiological data from the Heavy intensity exercise are reported in Table 4.

266

267   *Phase II amplitude*

268   A significant Test (baseline, post-intervention) by Exercise Condition (EX, CON) by weight status

269   (OB, NW) interaction was observed for the phase II amplitude (P<.05). Post hoc analysis revealed the

270   following: a significant decrease in the OB children phase II amplitude between baseline and post-

271   intervention for EX (P<.01), a significant increase in the OB children phase II amplitude between

272   baseline and post-intervention for those in CON (P<.05), a significantly lower phase II amplitude for

273   OB children at post-intervention for EX compared to CON (P<.001) and that NW children elicited a

274   lower phase II amplitude than OB children, regardless of the Exercise Condition or Test (all P<.001).

275

276   *Phase II gain*

277   A significant Test by Exercise Condition by weight status interaction was observed for the phase II

278   gain (P<.05). Post hoc analysis demonstrated the following: a significant decrease in the phase II gain

279   between baseline and post-intervention for OB children taking part in EX (P<.001), significantly

280   lower values for OB children taking part in EX than OB children randomised to CON at the post-

281 intervention assessment ($P<.001$), and that NW children (EX & CON) elicited lower values than OB

282 children (EX & CON) at both the baseline and post-intervention assessments ($P<.001$).

283 *MRT*

284 A Test by Exercise Condition interaction was observed for MRT, with a significant decrease reported

285 from baseline to post-intervention for EX (47.4 ± 8.8 to 40.5 ± 9.7 s, respectively), but not for CON

286 (45.7 ± 8.9 to 46.1 ± 9.8 s, respectively) ($P < .05$).

287

288 *Phase II time delay*

289 A significant Test by Exercise Condition by weight status interaction was observed for the phase II

290 time delay with the greatest change reported between the baseline and post-intervention assessment

291 for OB children ($P<.05$).

292

293 *Phase II τ*

294 A significant Test by Exercise Condition by weight status interaction was also revealed for τ ($P<.05$).

295 Post hoc analysis demonstrated a greater decrease in the OB children phase II τ between baseline and

296 post-intervention for EX than all other conditions ($P<.01$), as shown in Figure 1.

297

298 *Slow Component*

299 A slow component was observed in all participants during heavy intensity exercise, but was not

300 influenced by weight status, Exercise Condition or Test, irrespective of the method of expression (all

301 $P>.05$).

302

303 **Discussion**

304 The main finding of the present study was that a six-week high-intensity, games-orientated
305 intervention significantly influenced the $\dot{V}O_2$ kinetic response of obese pre-pubertal children.
306 Specifically, and in accordance with our hypothesis, the obese children demonstrated a significantly
307 faster phase II τ and MRT and reduced phase II amplitude during heavy intensity exercise. The
308 intervention did not influence the dynamic $\dot{V}O_2$ response in the normal weight children. These
309 findings demonstrate that postive improvements in the dynamic $\dot{V}O_2$ response of obese children may
310 be elicited following regular participation in just six weeks of high-intensity exercise.

311

312 The current study is the first to investigate the influence of an exercise intervention on the dynamic $\dot{V}$
313 O_2 response of obese pre-pubertal children. In this study, a slower phase II τ was observed at baseline
314 in the obese children, supporting some (Lambrick, Faulkner et al. 2013), but not all (Cooper et al.
315 1990; Rasmussen et al. 2000; Unnithan et al. 2007), previous research. Interestingly, a significant
316 speeding of the phase II τ (20%) and MRT (24%) and reduction of the phase II amplitude (11%) was
317 observed in obese children during heavy intensity exercise following the exercise intervention. Whilst
318 direct comparisons are precluded, it is pertinent to note that long-term, intensive training has been
319 reported to elicit a phase II τ that is 32% faster than that observed in untrained counterparts (Winlove,
320 Jones et al. 2010). This is remarkably similar to that observed in the present study and demonstrates
321 the efficacy of our short-term exercise intervention; a programme which reflects the high-intensity
322 nature of children's play patterns (Bailey, Olson et al. 1995). These findings further support those
323 which suggest peak $\dot{V}O_2$ may lack sensitivity to changes in fitness (Impellizzeri, Marcora et al. 2005;
324 Meyer, Lucia et al. 2005) and highlight the superior sensitivity of $\dot{V}O_2$ kinetics.

325

326 It is of interest to note that the influence of this exercise programme was weight-status dependent;
327 specifically no change was observed following the intervention in the normal weight children
328 irrespective of exercise intensity. As exercise-induced improvements are inversely related to the initial
329 baseline fitness of an individual (Eliakim et al. 1996; Mandigout et al. 2001), the relatively high level

of fitness of the normal-weight children at the start of the programme may plausibly have necessitated

a greater training stimulus for significant effects of the intervention to be observed in this population.

In healthy individuals during upright exercise, the dynamic $\dot{V}O_2$ response is purported to be predominantly determined by factors inherent to the mitochondria. Specifically, the delayed activation of oxidative phosphorylation at the onset of exercise is suggested to be partially attributable to determinants such as pyruvate dehydrogenase (Grassi et al. 2002), nitric oxide (Jones et al. 2003; Jones et al. 2004) and the PC-Cr shuttle concept of regulation (Grassi 2005). However, there may be circumstances, such as certain pathologies or exercise conditions that are associated with an altered microvascular O_2 partial pressure of a muscle fibre or the fibre type recruitment profile, in which rate of the $\dot{V}O_2$ response is determined by oxygen delivery. Consequently, it is now widely accepted that these two factors may co-exist on a continuum, distinguished by a "tipping point" in muscle oxygen delivery. Therefore, the faster $\dot{V}O_2$ kinetics observed post-intervention in the obese children in the present study may be attributable to an improved muscle oxygen delivery and/or to a greater muscle oxidative capacity. Indeed, while information regarding the muscle oxidative capacity of children is almost non-existent (Mahon 2008), the limited information available suggests that training may elicit an increased muscle oxidative enzyme activity (Eriksson et al. 1973; Fournier et al. 1982). An increased mitochondrial volume following endurance training would be predicted to result in faster $\dot{V}O_2$ kinetics (Meyer 1988). Whether similar adaptations occurred in the present obese population remains to be elucidated. However, when considering the mechanistic basis for the significant speeding of the phase II response in the present obese children, it may be pertinent to consider the greater proportion of type II muscle fibres reported in obese participants (Kriketos et al. 1997). Type II muscle fibres are characterised by a higher glycolytic but lower oxidative capacity than type I fibres (Crow et al. 1982; Krustrup et al. 2008). In addition, evidence suggests that type II fibres are less efficient, fatigue more easily and elicit lower microvascular O_2 partial pressures, both across the transient phase and during steady state exercise (Coyle et al. 1992; Behnke et al. 2003; McDonough et al. 2005). These differences are likely to exert considerable influence on the overall $\dot{V}O_2$ kinetics

357 exhibited, as supported by the inherently slower $\dot{V}O_2$ response reported in type II relative to type I

358 muscle fibres (Crow and Kushmerick 1982; Krustrup, Secher et al. 2008). Thus, although it is

359 presently uncertain whether the aforementioned findings are applicable to paediatric populations, an

360 altered proportion or recruitment pattern of type II muscle fibres in the obese children post-

361 intervention may contribute to the faster phase II τ observed.

362

363 In accordance with our previous study (Lambrick, Faulkner et al. 2013), a similar $\dot{V}O_2$ slow

364 component amplitude was observed between the obese and normal weight children, irrespective of

365 weight status, exercise participation (EX vs. CON) or assessment session (baseline, post-intervention).

366 Although the aetiology of the slow component remains to be conclusively elucidated, ~90% of this

367 component has been shown to arise from within the exercising muscle (Poole, Schaffartzik et al.

368 1991; Rossiter et al. 2002b), with the recruitment of additional (less efficient) type II muscle fibres

369 widely purported (Rossiter et al. 2002a; Krustrup et al. 2004). These findings are therefore contrary to

370 what we would hypothesise, as a reduced reliance on type II fibres might be expected to be associated

371 with a reduced slow component magnitude. However, since muscle fibre type distribution and

372 abundance was not assessed in the present study, further interpretation is beyond the scope of the

373 current study. It is prudent to note, however, that the similar slow component amplitudes observed in

374 the present participants might be a reflection of a slower development of this component in the obese

375 individuals, i.e. the slow component might not have been fully manifest at 6 minutes in the obese

376 children, artificially causing it to appear diminished.

377

378 The exercise intervention utilised in the present study demonstrated high rates of adherence (94%)

379 and consequently proved highly successful in eliciting significant physiological adaptations.

380 However, the present study is not without its limitations. Bias may have been introduced into the

381 study as a result of voluntary participant recruitment, i.e., children who 'like' exercise wished to be

382 involved in the study and as such, this may be reflected in the high peak $\dot{V}O_2$ values observed pre-

383 intervention, irrespective of weight-status. In terms of the findings, whilst a high baseline fitness may

384 explain the absence of an effect within the normal-weight children, it also indicates that the

385 intervention programme may have an even greater influence in a more representative obese

386 population. No measures of habitual physical activity were taken post-intervention, therefore it is not

387 presently possible to account for the effect of any potential changes in habitual physical activity and

388 their influence of the results observed. Finally, It is suggested that several repeat transitions are

389 needed for reliable characterisation of $\dot{V}O_2$ kinetic response (Lamarra et al. 1987). Although the

390 current study only utilised one transition, the confidence intervals during heavy intensity exercise are

391 nonetheless within those advocated by Fawkner and Armstrong (2007).

392

393 In conclusion, the present study demonstrates that a six week, high-intensity, games-orientated

394 intervention significantly improved the $\dot{V}O_2$ kinetic response of obese, pre-pubertal children.

395 Specifically, during heavy intensity exercise, the obese children demonstrated a 20% faster primary

396 phase response, 24% faster MRT and an 11% lower phase II amplitude. These adaptations would be

397 expected to reduce metabolic perturbation and fatigue development in the transition from a lower to a

398 higher metabolic rate, and may therefore improve exercise tolerance. Furthermore, if sustained, they

399 may directly translate to a reduced O_2 cost of daily activities and thereby potentially enhance

400 functional capacity and quality of life.

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543   Figure 1. Pulmonary oxygen uptake response during heavy intensity exercise in a representative A)

544   obese and B) normal-weight participant pre (open circles) and post (closed circles) the exercise

545   intervention.