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**Cardiopulmonary exercise testing in children with Cystic Fibrosis: one centre's experience**

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1   **ABSTRACT**

2   **Background**

3   While exercise testing is increasingly used as a prognostic indicator in Cystic Fibrosis  
4   (CF), it is reported to be underused in UK CF centres, particularly in children. Here,  
5   we evaluated the cardiopulmonary exercise testing (CPET) results in children and  
6   young people with CF at CF annual review and its possible clinical value.

7  
8   **Method**

9   An observational study comparing CPET results using a cycle ergometer ramp test  
10   (peak oxygen uptake ( $VO_{2peak}$ )) and pulmonary function (forced expiratory volume in  
11   1 second ( $FEV_1$ )) was performed with body mass index (BMI) used as a disease  
12   severity marker. Data were identified from clinical case notes and our CF database.

13  
14   **Results**

15   Thirty-eight children and young people (mean age  $11 \pm 2.4$ ; range 7-14 years; 17  
16   males and 21 females) completed at least one CPET with 95 % achieving technically  
17   satisfactory tests allowing measurement of  $VO_{2peak}$ . Mean  $VO_{2peak}$  was  $107 \pm 17.6\%$   
18   predicted, range 74 - 150% predicted, with 8% having a reduced  $VO_{2peak}$  of <85% of  
19   predicted. Mean  $FEV_1$  z-score was  $-0.77 \pm 1.24$ , range -4.42 to 2.24. We did not  
20   demonstrate a significant correlation between  $VO_{2peak}$  % predicted and  $FEV_1$  z-score  
21   ( $r=0.25$ ,  $p=0.13$ ), or between  $VO_{2peak}$  % predicted and BMI z-score ( $r=-0.05$ ,  $p=0.77$ ).  
22   Twenty-eight of 38 completed a second CPET the following year with 71% showing a  
23   decline in  $VO_{2peak}$ , (mean decline of 8% of predicted value, equivalent to 3.8  
24   mL/kg/min).

1   **Conclusion**

2   CPET is feasible with 95 % of children and young people achieving technically  
3   satisfactory assessments starting from age 7. In this group with relatively mild CF,  
4   mean  $VO_{2peak}$  was normal with no significant correlation between  $VO_{2peak}$  and  $FEV_1$  or  
5   BMI, as markers of disease severity. The majority demonstrated a normal  $VO_{2peak}$ .  
6   However, 71% showed a downward trend on repeat testing 12-18 months later.

7

8   **What is already known on this topic**

- 9       • Exercise testing is not widely used in cystic fibrosis (CF) centres in the UK.
- 10      • Peak oxygen uptake ( $VO_{2peak}$ ) and forced expiratory volume in 1 s ( $FEV_1$ ) are
- 11       independent predictors of mortality in CF.

12

13   **What this study adds**

- 14       • We demonstrate that it is feasible to include a cardiopulmonary exercise test
- 15       (CPET) as part of annual review in children and young people aged 7 years
- 16       and above.
- 17       • In mild disease, there is no significant correlation between  $VO_{2peak}$  and  $FEV_1$
- 18       or body mass index.
- 19       • A decline in fitness can be used as a trigger for more intensive physiotherapy
- 20       intervention.

21

22

23

24

## 1 INTRODUCTION

2  
3 Aerobic fitness has been found to be an independent predictor of mortality and  
4 morbidity in patients with cystic fibrosis (CF) [1,2,3]. At present, the UK CF trust  
5 guidelines recommend exercise testing at CF annual review when clinically indicated  
6 [4]. The European Cystic Fibrosis Exercise Working Group recommend that full  
7 cardiopulmonary exercise testing (CPET) should be performed routinely in children  
8 aged  $\geq 10$  years [5]. Exercise testing is reported to be underused in UK CF centres  
9 with field-based walking tests used most commonly [6]. To our knowledge, there are  
10 no studies assessing the prognostic value of the 6 min walk test (6MWT) in children  
11 with CF, and only limited reports in adults [7]. The prognostic value of an incremental  
12 shuttle test [8] in children with CF is also unknown. In contrast, peak oxygen uptake  
13 ( $VO_{2peak}$ ) has been shown to predict mortality in children with CF [1,2].

14  $VO_{2peak}$  represents the maximal amount of oxygen that can be delivered by the  
15 cardiovascular system and used at the muscles and defines functional aerobic  
16 capacity of a person [9,10]. In view of the potential usefulness of  $VO_{2peak}$  as a guide  
17 to understanding any exercise limitation and for guiding the prescription of exercise  
18 programmes [11], our centre replaced an annual 6MWT with an annual CPET for all  
19 children and young people aged  $>7$  years from May 2013. Here, we review our  
20 experience of measuring  $VO_{2peak}$  using CPET and assess correlations with other more  
21 commonly used outcome measures such as pulmonary function test results and  
22 body mass index (BMI). We also investigated whether there was a difference in  
23 mean  $VO_{2peak}$  depending on sex, the presence of at least one DF508 mutation or a  
24 history of intravenous antibiotic treatment in the preceding year and whether there

1 were changes in aerobic capacity over time.

## 2 **MATERIALS AND METHODS**

### 3 **Study participants**

4 We retrospectively analysed data for children and young people regularly attending  
5 the CF clinic at the Royal Hospital for Sick Children, Glasgow, who were >7 years and  
6 who had completed at least one CPET between May 2013 and April 2016. Clinic  
7 treatment routines remained unchanged during the study period and the  
8 participants were clinically stable when tested.

9

### 10 **Anthropometry**

11 Height was recorded to the nearest 0.1 cm using a stadiometer (Holtan Limited, UK)  
12 [12]. Weight was measured with minimal clothing to the nearest 0.1 kg (Seca 704,  
13 Germany).

14

### 15 **Pulmonary function testing**

16 Before CPET, spirometry and lung volumes were measured using a Jaeger  
17 Masterscreen Body Plethysmograph (Jaeger V5.4, Germany). All pulmonary function  
18 measurements were carried out by an experienced paediatric physiologist according  
19 to American Thoracic Society/European Respiratory Society standards [13,14,15].

20

### 21 **Cardiopulmonary Exercise Testing**

22 A symptom-limited CPET was performed using an electronically braked cycle  
23 ergometer (Ergoline, Netherlands) with an incremental ramp protocol. Before each

test, the metabolic cart (Jaeger, CPX, Germany) was calibrated according to the instructions of the manufacturer. We used a Godfrey exercise protocol [16] modified to minimise large increments in power output. The cycle ergometer ramp ranged between 6.5 and 25 W/min. The ramp was increased every 10 s to minimise power output perception. To achieve an optimal test duration of 8-12 min, power output based on weight, predicted for each participant [17], was divided by 10 to give the rate of ramp increase. Participants received verbal encouragement to achieve as near to a maximal test as possible. The test was stopped when the participant could not maintain a cadence > 60 rpm even with verbal encouragement.  $\text{VO}_{2\text{peak}}$ , peak oxygen pulse ( $\text{VO}_2/\text{HR}_{\text{peak}}$ ) and peak minute ventilation ( $\text{VE}_{\text{peak}}$ ) were averaged over the last 30 s of the test. The gas exchange threshold was non-invasively identified using a combination of the 'V slope' method and ventilatory equivalents [9].

We considered a CPET technically satisfactory if one of the following three criteria were achieved at the end of the test: (1)  $\text{HR}_{\text{peak}}$  within 15 bpm of predicted maximum based on age; (2) respiratory exchange ratio (RER) > 1.1; or (3) plateau in  $\text{VO}_2$ .

## **Consent**

This study was a retrospective review of results from our standard clinical practice. As such, we did not seek informed consent for review of the data. All data of the patients were anonymised.

## **Statistical Analysis**

1 Demographic data (age, sex, genotype and intravenous antibiotic use) were  
2 expressed as means and SDs. Forced expiratory volume in 1 s (FEV<sub>1</sub>) was expressed in  
3 absolute terms and as z-scores using all age reference ranges [18]. Static lung  
4 volumes were expressed in absolute values and as z-scores using UK-derived  
5 paediatric reference ranges [19]. VO<sub>2peak</sub> was expressed in L/min, mL/kg/min and as  
6 % predicted using a published paediatric reference range [17].

7

8 The relation between disease severity and VO<sub>2peak</sub> was assessed in two ways: first, as  
9 the relation between VO<sub>2peak</sub> and BMI since it is well recognised that poor nutritional  
10 status negatively affects pulmonary disease [20,21] and then, as the correlation  
11 between VO<sub>2peak</sub> and intravenous antibiotic use in the preceding year. We included  
12 children and young people treated with intravenous antibiotics either for a CF  
13 exacerbation or routinely as part of their CF management.

14

15 To investigate relationships between VO<sub>2peak</sub> % predicted and FEV<sub>1</sub> z-score, BMI z-  
16 score and age, we used Pearson's correlation coefficient. For differences between  
17 mean VO<sub>2peak</sub> % predicted with sex and intravenous antibiotics, we used a two-  
18 sample t-test. A one-way analysis of variance was conducted to compare the effect  
19 of genotype (DF508 homozygous, DF508 heterozygous and 'other' genotypes) on  
20 VO<sub>2peak</sub> % predicted.

21

22 We used a paired t-test to check for statistically significant differences between  
23 initial and consecutive CPET parameters of aerobic fitness (absolute VO<sub>2peak</sub> (L/min);  
24 relative VO<sub>2peak</sub> (mL/kg/min); VO<sub>2peak</sub> % predicted; and finally, allometrically scaled

1 VO<sub>2peak</sub> (ml/kg<sup>2/3</sup>/min)). Relationships between the change in VO<sub>2peak</sub> % predicted and  
2 FEV<sub>1</sub> and BMI z-scores were studied using Pearson's correlation coefficient.

3

## 4 **RESULTS**

### 5 **Pulmonary function & anthropometry.**

6 Anthropometry and pulmonary function are summarised for the 38 participants  
7 studied (17 males, 21 females) in tables 1 and 2. Seven participants had an FEV<sub>1</sub>  
8 consistently below the lower limit of normal [19].

9

#### 10 **Table 1**

11

#### 12 **Table 2**

13

14 We were able to perform technically satisfactory assessments on 36/38 (95 %) of  
15 children and adolescents (Table 3); in two of them (both aged 7 years), the CPET was  
16 technically unsatisfactory due to poor cooperation. Aerobic capacity in children with  
17 CF was within a range consistent with a normal, healthy population (VO<sub>2peak</sub> of ≥85 %  
18 predicted [22]). Only five participants (13 %) had VO<sub>2peak</sub> of <85 % predicted, none of  
19 whom had reduced FEV<sub>1</sub>. Two participants desaturated to SpO<sub>2</sub> (oxygen saturation  
20 as measured by pulse oximetry) <95 % at peak exercise. No ECG arrhythmias were  
21 detected.

22

#### 23 **Table 3**

24

1 We found no significant correlation between  $VO_{2peak}$  % predicted and  $FEV_1$  z-score ( $r$   
 2  $=0.25$ ,  $p=0.13$ ),  $VO_{2peak}$  % predicted and age ( $r = -0.24$ ,  $p=0.15$ ) or between  $VO_{2peak}$  %  
 3 predicted and BMI z-score ( $r = -0.05$ ,  $p=0.77$ ). Using a two-sample t-test, we found  
 4 no significant differences in mean  $VO_{2peak}$  between males ( $107.9 \pm 19.1\%$  predicted) vs  
 5 females ( $107.1 \pm 17.0\%$  predicted),  $p=0.90$ . Fourteen children and young people had  
 6 received intravenous antibiotics in the preceding year with no significant differences  
 7 in mean  $VO_{2peak}$  if they had intravenous antibiotics ( $103.0 \pm 18.5\%$  predicted) vs did  
 8 not have intravenous antibiotics ( $110.1 \pm 17.1\%$  predicted),  $p=0.23$ . Nineteen children  
 9 and young people were DF508 homozygous, 16 were DF508 heterozygous and 3 had  
 10 'other' genotypes with no significant effect of genotype on  $VO_{2peak}$  ( $p=0.567$ ).

11

12 **Figure 1.** Change in  $VO_{2peak}$  % predicted in 28 children and adolescents with CF  
 13 measured between 12-18 months apart

14

15 **Table 4**

16

17 Consecutive annual CPET data were available for 28/38 (74%) children and young  
 18 people (Figure 1), up to 18 months after the initial CPET due to CF annual review  
 19 timings. The results for those who completed a second CPET are shown in table 4.  
 20 Ten did not perform a repeat CPET: three transitioned to adult services; four did not  
 21 attend; one had an intercurrent CF exacerbation; one CPET was unsatisfactory due  
 22 to submaximal effort and there was insufficient staffing for one patient. Mean  
 23 increase in body mass from test 1 to test 2 was 4.9 kg and height was 6.5 cm. There  
 24 was no significant difference in mean change of absolute  $VO_{2peak}$  ( $p=0.74$ ). However,

1 there was a statistically significant decline in  $\text{VO}_{2\text{peak}}$  when it was related to body  
2 weight ( $p=0.001$ ), to % predicted  $\text{VO}_{2\text{peak}}$  ( $p=0.003$ ), which includes sex and body  
3 weight in the predicting equation, and when using allometric scaling ( $\text{mL/kg}^{2/3}/\text{min}$ )  
4 ( $p=0.03$ ). Seventy-one per cent of patients had a decline in  $\text{VO}_{2\text{peak}}$  relative to body  
5 weight. The mean decline relative to body weight was  $3.8 \text{ mL/kg/min}$  equivalent to  
6 an 8% decrease from baseline value. We found no significant correlation between  
7 the change in  $\text{VO}_{2\text{peak}}$  % predicted and the change in  $\text{FEV}_1$  z-score ( $r=-0.07$ ,  $p=0.72$ ) or  
8 between  $\text{VO}_{2\text{peak}}$  % predicted and the change in BMI z-score ( $r=0.10$ ,  $p=0.61$ ).

9

## 10 **DISCUSSION**

11 In this study, the majority of our children and young people with CF had BMI and  
12 pulmonary function within the normal range, in keeping with UK CF registry data  
13 [23]. The majority also had  $\text{VO}_{2\text{peak}}$  measurements within the normal range suggesting  
14 that they are an aerobically fit group.

15

16 We found no significant correlation between  $\text{FEV}_1$  and  $\text{VO}_{2\text{peak}}$ , presumably explained  
17 by the majority having normal lung function and aerobic capacity. It is recognised  
18 that  $\text{FEV}_1$  has to be significantly reduced to affect exercise capacity [24]. For  
19 example, McBride et al investigated 64 children with CF aged 8-11 years and found a  
20 statistically significant but weak correlation between  $\text{FEV}_1$  % predicted and  $\text{VO}_{2\text{peak}}$  %  
21 predicted with an  $R^2$  value of 0.14[25]. The most likely explanation for the differences  
22 with our study is a combination of a larger sample and a wider range of lung function  
23 and fitness. As only seven of our participants had an  $\text{FEV}_1$  below the lower limit of  
24 normal, it is perhaps not surprising that we did not see a relationship in a relatively

1 mildly affected population [26]. However, taken together, the low  $R^2$  value in a study  
2 by McBride and the absence of any significant correlation in our data suggest no  
3 strong relationship between  $FEV_1$  and  $VO_{2peak}$ . Additionally, we did not demonstrate  
4 a significant correlation between the change in  $VO_{2peak}$  % predicted and change in  
5  $FEV_1$  or BMI z-score in our CF group, highlighting that these measurements cannot be  
6 used as a surrogate marker for aerobic fitness. There is an ongoing debate about  
7 factors that limit aerobic function in CF with suggestions of both central (e.g.  
8 impaired stroke volume [27]) and/or peripheral mechanisms (e.g. impaired muscle  
9 metabolism) being involved, apart from changes in lung function [28].

10  
11 There are varying reports in the literature on the aerobic fitness of CF children. Nixon  
12 et al investigated  $VO_{2peak}$  and its prognostic value in a group of 40 adults and 68  
13 children and adolescents in whom 65 % had an  $FEV_1$  of <65 % predicted. They found  
14 low aerobic capacity with a mean  $VO_{2peak}$  of 70% predicted (35 mL/kg/min) [1]. More  
15 recently, Hulzebos et al reported on 127 adolescents with CF who had a mean  $FEV_1$   
16 of  $78 \pm 15.6$  % predicted and a  $VO_{2peak/kg}$   $93 \pm 17.9$  % predicted [3]. Pianosi et al  
17 exclusively investigated children with CF and reported an initial  $VO_{2peak}$  of 41.2  
18 mL/kg/min [2]. This would be classed as 'fair' aerobic fitness according to published  
19 paediatric reference values [24].

20  
21 More recent studies have included control groups and showed that children and  
22 adolescents with CF had a significantly reduced  $VO_{2peak}$  when compared to healthy  
23 children. For example, Bongers et al in a group of 22 children with CF, found  
24  $VO_{2peak}$  to be significantly lower than healthy controls [29] and Saynor et al found a

1 reduced aerobic capacity (mean  $\text{VO}_{2\text{peak}}$  36.3 mL/kg/min) in those with CF compared  
2 with controls [30].

3

4 Other studies have reported that nutritional status affects exercise capacity [31,32]  
5 but since very few of the children in our study had either an abnormal BMI or an  
6 abnormal  $\text{VO}_{2\text{peak}}$  ( $\leq 84\%$  predicted (range 64 – 84)) [22] we were unable to  
7 demonstrate a significant correlation. On reviewing the 3 participants with an  
8 abnormal  $\text{VO}_{2\text{peak}}$ , all had normal BMI z-scores (-0.57, 1.13, 1.83).

9

10 While the majority of our patients had normal CPET results, 71% demonstrated a  
11 decline in  $\text{VO}_{2\text{peak}}$  relative to body weight on repeat testing 12- 18 months later. We  
12 recognise that in the absence of a control group and more extensive longitudinal  
13 data, it is difficult to exclude normal variation and regression to the mean as a cause  
14 of this decline and indeed, we found some evidence of regression to the mean.  
15 (Supplementary Figure).

16

17 There is little reported data about what constitutes a significant decline in  $\text{VO}_{2\text{peak}}$  in  
18 patients with CF. It is also unclear how changes with growth in weight and height  
19 should be accounted for when reporting  $\text{VO}_{2\text{peak}}$  data, both in healthy children and in  
20 those with CF, particularly around puberty. In a review by Krahenbuhl et al of data  
21 from healthy children, mean values of  $\text{VO}_{2\text{peak}}$  relative to body weight were plotted  
22 against age in males and females over the age range 6-16 years [33]. Males had an  
23 unchanged  $\text{VO}_{2\text{peak}}$  corrected for body weight over time, whereas females showed a  
24 decline from 52.0 to 40.5 mL/kg/min.

1

2 It is recognized that correcting  $VO_{2peak}$  for body mass has limitations and does not  
3 normalise the data [34,35]. Ratio scaling of  $VO_{2peak}$  by body mass (as opposed to fat-  
4 free mass) penalises females and those that are heavier than their aged match peers.  
5 Allometric scaling of  $VO_{2peak}$  may be a more reliable method to interpret changes in  
6  $VO_{2peak}$  [36], particularly in the transition at puberty. In a cross-sectional study using  
7 allometric scaling, Armstrong and Welsman reviewed prepubertal, circumpubertal  
8 and adult males and females, and found significant increases in  $VO_{2peak}$  when  
9 allometrically scaled relative to weight in males throughout the maturational range,  
10 whereas females increased till puberty then remained stable [37]. In contrast, the  
11 Amsterdam Growth and Health Longitudinal Study recently reported aerobic fitness  
12 for approximately 650 adolescents over a 25-year period. They found that from 12 to  
13 17 years in both males and females, there was a downward trend in  $VO_{2peak}$  relative  
14 to body weight. However, when allometrically scaled,  $VO_{2peak}$  in males did not  
15 decrease while females declined [38]. We found a mean decline relative to body  
16 weight of 3.8 mL/kg/min equivalent to an 8% decrease from baseline value. This is  
17 greater than the normal coefficient of variation reported in the literature for  $VO_{2peak}$   
18 (4.8%) when looking at biological quality control subjects [39], although the  
19 variability for young patients with CF is likely to be greater [40]. In our data, aerobic  
20 fitness declined significantly, irrespective of whether  $VO_{2peak}$  was related to body  
21 weight, % predicted values or using allometric scaling (table 4), although the decline  
22 was least using allometric scaling.

23

1 Pianosi et al reviewed annual CPET over a 5 year period in children with CF and  
2 found that  $VO_{2peak}$  decreased in 70% of children with a mean annual decline of 2.1  
3 mL/kg/min [2]. Although measured over a much shorter time period, our results are  
4 similar. We can only speculate on the reasons for the decline in some children.  
5 Although changes in lung function measured as  $FEV_1$  were not correlated with  
6 changes in aerobic fitness, acute exacerbations as well as disease progression may  
7 have resulted in these patients participating in less physical activity with a  
8 consequent reduction in fitness. In others, an increase in fitness may result from the  
9 effects of planned exercise interventions. Pianosi also showed that initial  $VO_{2peak}$  did  
10 not affect the rate of decline and that patients with  $VO_{2peak} < 32$  mL/kg/min exhibited  
11 a dramatic increase in mortality [2]. Further work will be required to investigate the  
12 value of repeated CPET tests in assessing exercise capacity in CF patients over time.

13

14 Whilst the capital initial cost of CPET equipment is significant, the cost of  
15 consumables is minimal. Performing an annual CPET added minimal time to the CF  
16 annual review visit with 95% of children and young people aged above 7 years  
17 achieving technically satisfactory assessments. Nevertheless, CPET is a more  
18 technically demanding test and can only be performed in a centre with the necessary  
19 equipment and appropriately trained staff. The majority of our patients engaged well  
20 with the test and participants reported that they enjoyed the challenge. Importantly,  
21 our respiratory physiotherapists found the results helpful in identifying children  
22 needing more targeted exercise advice. This emphasizes the value of CPET as a  
23 clinical tool to guide the prescription and monitoring of exercise programmes [41].

24

## Study limitations

This was a retrospective review and we had no control group. Instead, we relied on published normal data for  $\text{VO}_{2\text{peak}}$ , data based on a limited number of North American children and published in 1984. Future research should focus on providing up-to-date reference data for UK children.

Only 74% ( $n = 28$ ) completed a second CPET during the study period and the follow-up period was relatively short at 12-18 months. We continue to collect data in the expectation that longer follow up will give a more informed assessment of extent and value of changes in aerobic capacity over time.

In the context of a paediatric clinical population, it was not feasible to perform a supramaximal test on each patient to verify a 'true'  $\text{VO}_{2\text{peak}}$  as demonstrated by a plateau in  $\text{VO}_2$ . The use of secondary criteria of  $\text{HR}_{\text{peak}}$  and RER may, therefore, underestimate the 'true'  $\text{VO}_{2\text{peak}}$  [42]. We also did not routinely take body fat measurements but recognise that this may affect the  $\text{VO}_{2\text{peak}}$  % predicted which uses body weight in the predictive equation. Finally, we had no standardised recording of physical activity levels of the children and adolescents in the 12-18 month interval between the first and second tests, data that might have been informative in assessing the effect of regular activity and/or exercise on aerobic capacity.

## CONCLUSION

CPET is a feasible test of aerobic function at CF annual review. In our population with relatively mild CF, most had normal  $\text{VO}_{2\text{peak}}$ . While most children and young people

1 showed a decline in  $VO_{2peak}$  over time, it remains to be shown if these declines are  
2 clinically significant or are part of normal biological variation.

3

#### 4 **Acknowledgements**

5 We would like to thank all the patients who performed PFT's and CPET during the  
6 study period and our physiotherapy team who contribute to maintaining aerobic  
7 fitness in our patients with CF.

8

#### 9 **Contributorship**

10 AD instigated, designed and supervised the study. EW and PB contributed to the  
11 design of the study, collected the data and analysed results with DY. EW and PB  
12 wrote the article. JYP reviewed and commented on the article.

13

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16

#### 17 **Competing interests**

18 None declared

19

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**Table 1**

Variable	mean	SD	Min, max Range
Age (years)	11.0	2.39	7.3, 15.7
Height (cm)	142.9	16.82	115, 180.8
Body mass (kg)	36.9	12.32	20.2, 69.5
BMI z-score	0.09	1.05	-2.2, 2.5

**Table 2**

Variable	mean	SD	Min, max Range
FEV <sub>1</sub> (L)	2.1	0.75	0.98, 4.06
FEV <sub>1</sub> z-score	-0.77	1.24	-4.42, 2.24
FEV <sub>1</sub> /FVC (%)	81	8.5	57, 96
FEV <sub>1</sub> /FVC (%) z-score	-0.99	1.24	-3.64, 1.55
TLC (L)	3.7	1.15	2.04, 7.01
TLC z-score	0.70	1.04	-1.08, 3.17
RV (L)	1.1	0.49	0.58, 2.58
RV z-score	0.59	1.75	-1.48, 6.61

**Table 3**

Variable	Mean	SD	Min, Max Range
<i>Maximal Exercise parameters</i>			
Absolute VO <sub>2peak</sub> (L·min <sup>-1</sup> )	1.6	0.52	0.88, 3.01
Relative VO <sub>2peak</sub> (ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	42.8	7.99	29.2, 62.3
VO <sub>2peak</sub> (% predicted)	107	17.6	74, 150
VE max (L·min <sup>-1</sup> )	64	23.5	28, 137
Breathing reserve (%)	19	19.8	-36, 54
Heart Rate max (Beats·min <sup>-1</sup> )	188	10.2	160, 208
Oxygen Pulse max (ml·beat <sup>-1</sup> )	8.6	2.77	4.0, 16.0
End test SpO <sub>2</sub> (%)	97	2.0	89, 100
Peak power Output (W)	97	41.9	41, 212
Relative Peak power output W·kg <sup>-1</sup> )	2.5	0.56	1.6, 3.8
<i>Submaximal Exercise</i>			
VO <sub>2</sub> at GET (ml·min <sup>-1</sup> )	822	216.1	415, 1455
GET (% of VO <sub>2peak</sub> )	53	7.3	38, 70
VO <sub>2</sub> /Work Rate (ml·W <sup>-1</sup> ·min <sup>-1</sup> )	10.6	0.88	9.1, 12.3
VE/VCO <sub>2</sub> Slope	30.9	3.87	22.4, 44.0

GET - Gas exchange Threshold

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**Table 4**

Variable	Mean <sub>1st CPET</sub>	Mean <sub>2nd CPET</sub>	Absolute Difference	% Difference
VO <sub>2peak</sub> (L·min <sup>-1</sup> )	1525 ± 479.7	1539 ± 420.4	14	1
VO <sub>2peak</sub> Relative to bodyweight (ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	42.7 ± 6.95	38.9 ± 8.19	-3.8	-9
VO <sub>2peak</sub> % Predicted (includes sex and body weight)	107 ± 16.6	99 ± 16.8	-8	-8
VO <sub>2peak</sub> Allometrically scaled (ml·kg <sup>-2/3</sup> ·min <sup>-1</sup> )	137 ± 21.7	130 ± 21.9	-7	-6
Body mass (kg)	36.2 ± 12.28	41.2 ± 13.51	4.9	13.6
Body mass z-score	0.04 ± 0.97	0.06 ± 0.93		
Height (cm)	141.8 ± 15.11	148.3 ± 15.14	6.5	4.6
Height z-score	0.03 ± 1.21	0.02 ± 1.13		