

# Submaximal Oxygen Uptake Efficiency Slope as a Predictor of VO<sub>2</sub>max in Men with Cardiovascular Disease



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## ABSTRACT

**Purpose:** Although VO<sub>2</sub> max is considered the gold standard measure of cardiorespiratory fitness (CRF), it can be difficult to attain in patients with cardiovascular disease (CVD). The submaximal oxygen uptake efficiency slope (OUES) integrates cardiovascular, musculoskeletal and respiratory function during incremental exercise into a single index and has been proposed as an alternative and effort independent measure of cardiopulmonary reserve (Baba et al., 1996). The purpose of this study was to examine the relation between VO<sub>2</sub> max and both submaximal absolute OUES and relative OUES (OUES·kg<sup>-1</sup>).

**Methods:** A total of 55 men ((mean ± SD) age, 59.08 ± 9.03 yr; VO<sub>2</sub> max, 1.94 ± 0.53 L·min<sup>-1</sup> and 22.73 ± 5.95 mL·kg<sup>-1</sup>·min<sup>-1</sup>) were recruited during induction to a community based exercise referral program following completion of phase 2 cardiac rehabilitation. Participants performed a graded exercise test on a cycle ergometer with breath-by-breath open circuit spirometry and a 12 lead ECG. Absolute OUES and OUES·kg<sup>-1</sup> were calculated by plotting VO<sub>2</sub> in mL·min<sup>-1</sup> on the x-axis, and the log transformed V<sub>E</sub> on the y-axis (VO<sub>2</sub> = a log<sub>10</sub> V<sub>E</sub> + b). Exercise data up to the ventilatory anaerobic threshold (VAT) was included in the analysis.

**Results:** The %VO<sub>2</sub> max corresponding to the VAT was 55.72 ± 11.81. Absolute OUES and OUES·kg<sup>-1</sup> were 2164.42 ± 540.96 and 25.28 ± 5.99, respectively. There was a significant positive correlation between VO<sub>2</sub> max (L·min<sup>-1</sup>) and OUES (r = 0.775; p < 0.001) and between VO<sub>2</sub> max (mL·kg<sup>-1</sup>·min<sup>-1</sup>) and OUES·kg<sup>-1</sup> (r = 0.78; p < 0.001).

**Conclusion:** Determination of VO<sub>2</sub> max is not often feasible in individuals with CVD where maximal exercise testing is contraindicated or when performance may be impaired by pain, dyspnea or angina. The findings from the present study indicate that the OUES and OUES·kg<sup>-1</sup> are significantly related to absolute and relative VO<sub>2</sub> max, respectively and may be used as a valid submaximal effort independent measure of CRF.

## INTRODUCTION

Cardiovascular disease (CVD) refers to diseases of the heart and circulatory system. Globally, CVD is responsible for over 17.3 million deaths annually and accounts for 45% of non-communicable deaths. Improvement in VO<sub>2</sub> peak/max is associated with a significant reduction in both all-cause mortality and cardiovascular mortality in men and women with CVD. However, determination of VO<sub>2</sub> max is not often feasible in individuals with CVD where maximal exercise testing is contraindicated or when performance may be impaired by pain, dyspnea or angina.

OUES is an effort independent submaximal CRF parameter that is derived from the linear relation of VO<sub>2</sub> (y-axis) versus the logarithm of V<sub>E</sub> (x-axis) during incremental exercise. It provides an estimation of the efficiency of ventilation with respect to VO<sub>2</sub>, with greater slopes indicating greater ventilatory efficiency. It is relatively independent of patient-achieved effort levels and reflects the absolute rate of increase in VO<sub>2</sub> per 10-fold increase in ventilation.

The purpose of this study was to examine the relation between VO<sub>2</sub> max and submaximal absolute OUES and submaximal relative OUES (OUES·kg<sup>-1</sup>).

## METHODOLOGY

- A total of 55 men with stable CVD made a single visit to Dublin City University
- Height, weight, hip and waist circumference were measured and participants performed a maximal cardiopulmonary exercise test (CPET) with a 12-lead ECG
- Breath-by-breath gas collected during the CPET was averaged at 20 s intervals
- OUES was calculated using the equation; VO<sub>2</sub> = a log<sub>10</sub> V<sub>E</sub> + b where the constant 'a' represents OUES, 'log<sub>10</sub> V<sub>E</sub>' represents the logarithm of V<sub>E</sub> and the constant 'b' represents the intercept (Figure 1)
- The ventilatory breakpoint method was used to determine VAT (Figure 2)

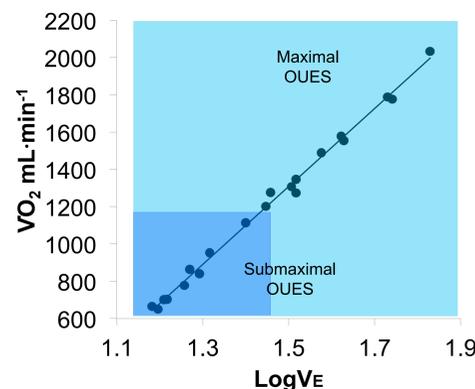


Figure 1. Max and submax OUES calculation

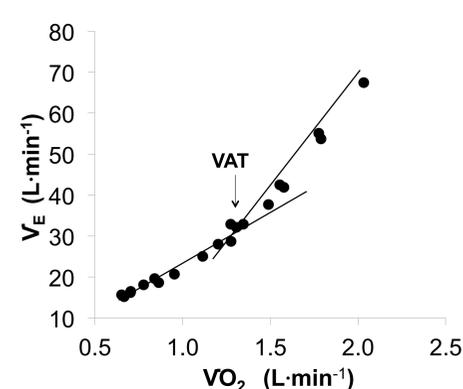


Figure 2. Calculation of VAT

Table. Physiological and physical characteristics, CV events and medications

Variable	Value
Age (y)	59.08 ± 9.03
VO <sub>2</sub> max (L·min <sup>-1</sup> )	1.94 ± 0.53
VO <sub>2</sub> max (mL·kg <sup>-1</sup> ·min <sup>-1</sup> )	22.73 ± 5.95
V <sub>E</sub> max (L·min <sup>-1</sup> )	67.68 ± 23.66
Max workrate (watts)	140.00 ± 42.26
Max heart rate (b·min <sup>-1</sup> )	135.19 ± 19.36
BMI (kg·m <sup>2</sup> )	28.95 ± 3.73
Waist:hip	0.97 ± 0.05
Systolic blood pressure (mm Hg)	136.97 ± 17.32
Diastolic blood pressure (mm Hg)	83.59 ± 7.89
Resting heart rate (b·min <sup>-1</sup> )	66.12 ± 10.67
<b>Cardiovascular Event</b>	
MI	23 (41)
STEMI	14 (25)
NSTEMI	9 (16)
PCI	48 (87)
CABG	7 (12)
<b>Medications</b>	
Statins	51 (92)
Anti-platelets	49 (89)
Beta blockers	42 (76)
ACE inhibitors	25 (45)
ARB's	8 (15)

Values are mean ± SD and total number (percentage)

## RESULTS

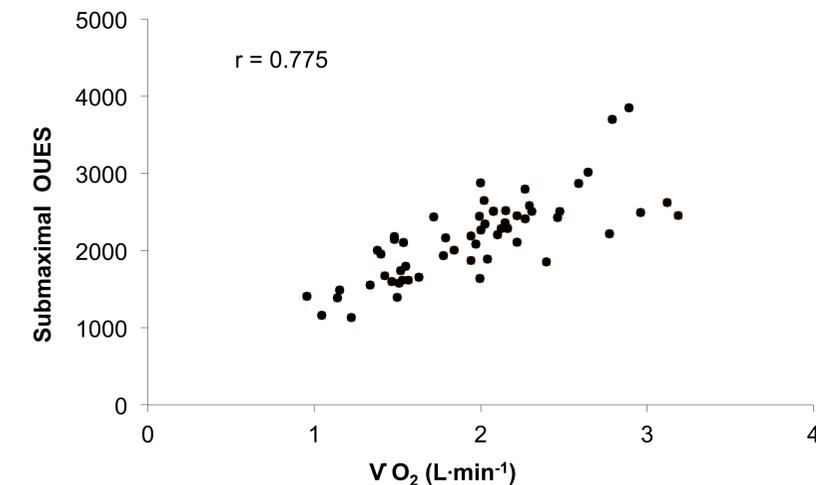


Figure 3. Relation between absolute VO<sub>2</sub> max and absolute OUES

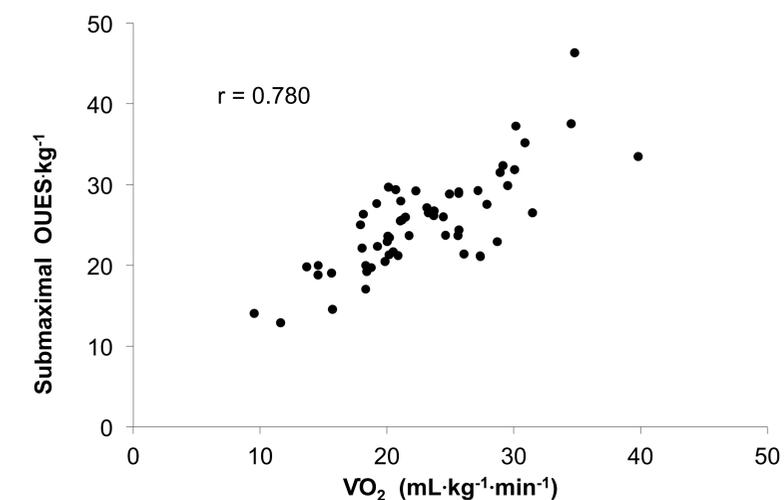


Figure 4. Relation between relative VO<sub>2</sub> max and relative OUES

## CONCLUSION

Determination of VO<sub>2</sub> max is often not feasible in individuals with CVD where maximal exercise testing is contraindicated or when performance may be impaired by pain, dyspnea, angina or anxiety. The findings from the present study indicate that the submaximal OUES and OUES·kg<sup>-1</sup> are significantly related to absolute and relative VO<sub>2</sub> max, respectively, and may be used as a valid submaximal effort independent measure of CRF in men with stable CVD.

## ACKNOWLEDGEMENTS

This project has been funded by EU's Horizon 2020 Framework Program for Research and Innovation Action under Grant Agreement no. 643491. PATHway: Technology enabled behavioral change as a pathway towards better self-management of CVD. ([www.pathway2health.eu](http://www.pathway2health.eu))