

LifeQ

LifeQ VO₂ max solution v2.0

Updated June 2016

Table of contents

Introduction.....2
 Test Protocol.....3
 Results.....4
 Conclusion4
 References5

Summary

- VO₂ max is the most frequently used measure of cardiorespiratory fitness
- The gold standard for VO₂ max measurement is an expensive, time consuming indirect calorimetry test performed in a laboratory setting, making it unsuitable for frequent or continuous monitoring and is inaccessible to most
- The *LifeQ VO₂ max solution v2.0* estimates VO₂ max using a single-stage submaximal VO₂ max test and heart rate, and does not require specialized equipment
- Estimations by the *LifeQ VO₂ max solution v2.0* shows a strong correlation with gold standard laboratory VO₂ max measurements of R = 0.901, with a mean absolute percentage error of 9.7%

Key terms

- **VO₂ max** = maximum volume of oxygen that can be utilized by the body (typically measured during maximum exertion exercise) in ml/min/kg.

Introduction

Maximal oxygen consumption (VO₂ max) refers to the maximum amount of oxygen utilized by the body per kilogram of body weight, per minute. VO₂ max is the most frequently used measure of cardiorespiratory fitness, and is a valuable

tool in the calculation of other physiological parameters such as VO₂, energy expenditure and excess post exercise oxygen consumption.

The current gold standard for VO₂ max measurement requires a highly intensive laboratory-based test that demands maximal physical effort. The test consists of a graded exercise test (GXT) that typically uses indirect calorimetric techniques, requiring specialized and expensive laboratory equipment including a metabolic cart, gas mask, chest strap and treadmill (Figure 1), administered by a trained laboratory technician. The test requires the measurement of inhaled and exhaled gas concentrations while the exercise intensity is progressively increased to push the aerobic energy system to its maximal capacity. The highly specialized equipment and invasive nature of the laboratory based VO₂ max determination makes this method inaccessible to most.

The *LifeQ VO₂ max solution v2.0* uses a single-stage submaximal VO₂ max treadmill test, which requires heart rate (HR) measurements during a comfortable treadmill protocol, eliminating the need for an exhaustive exercise test and specialized equipment.



Figure 1: Example of a gold standard VO₂ max measurement using a treadmill, a metabolic cart, a chest strap HR monitor and a gas mask.

Test Protocol

The LifeQ VO₂ max test was validated against the gold standard laboratory-based VO₂ max GXT using indirect calorimetry. The LifeQ VO₂ max test and the gold standard laboratory-based VO₂ max test were performed on consecutive days, with the the gold standard laboratory-based VO₂ max test performed on the day after the LifeQ VO₂ max test.

This validation study included 126 participants with a mean age 33.5 years (21.3, 32, 49.5)*, 45 female and 81 male. The mean BMI was 26.8 (19.4, 25.2, 37.5)* and the mean VO₂ max was 41.5 ml/min/kg (23.4, 43.1, 59.0)*.

The following physiological parameters were collected for each participant:

- Height (m)
- Age (yrs)
- Weight (kg)
- Gender
- Resting heart rate (beats per min)
- Actual VO₂ max (measured by indirect calorimetry) (ml/kg/min).

* 5th percentile, median, 95th percentile

For the LifeQ VO₂ max test HR was measured continuously using an ECG chest strap. Participants began with a 3-minute warm-up walk on a treadmill, followed by a jog at a comfortable self-selected speed between 7 and 12 km/h, at a pace that did not let the HR rise above 180 beats per minute for approximately 3 minutes (until a steady HR was achieved). Using the continuous ECG HR data, combined with the basic physiological parameters described above, a VO₂ max value was estimated for each participant using the *LifeQ VO₂ max solution*.

For the gold standard laboratory VO₂ max test, test participants were asked to refrain from caffeine and alcohol use less than 12 hours before the test, eating and drinking (except for water) less than 3 hours before the test and performing any exercise less than 24 hours before the test. Resting heart rate and VO₂ max were measured using a chest strap heart rate monitor, a BioHarness™ device, a gas mask and a metabolic cart. Following a resting protocol of 35 minutes, participants started walking on the treadmill at a speed of 1 km/h, which was incremented by 1 km/h each minute up to 8 km/h after which the speed was incremented only every 3 minutes, until the participant reached voluntary exhaustion. Respiratory gas exchange was monitored and VO₂ max was defined as the highest average VO₂ value over a 30 second steady-state period¹ (Figure 5).

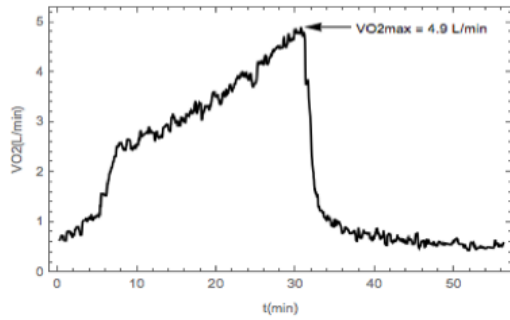


Figure 5: Oxygen consumption (VO₂) during an individual VO₂ max graded exercise test (GXT). The recorded VO₂ max is indicated by the arrow.

The *LifeQ VO₂ max solution v2.0* was compared to the gold standard laboratory based VO₂ measurements obtained using indirect calorimetry during graded exercise. The accuracy, expressed as a mean absolute percentage error (MAPE), was determined as follows:

$$MAPE = \frac{100}{N} \times \sum_{VO_{2max}=1}^N \left| \frac{(measured\ VO_{2max}) - (predicted\ VO_{2max})}{measured\ VO_{2max}} \right|$$

Where N = the number of datasets in the study.

Results

A comparison of the outputs of the *LifeQ VO₂ max solution v2.0* and the laboratory-based measured VO₂ max of each test participant is presented in Figure 6 with a correlation of R = 0.901 between the estimated and measured VO₂ max and a MAPE of 9.7% (0.4, 6.8, 28.8)*.

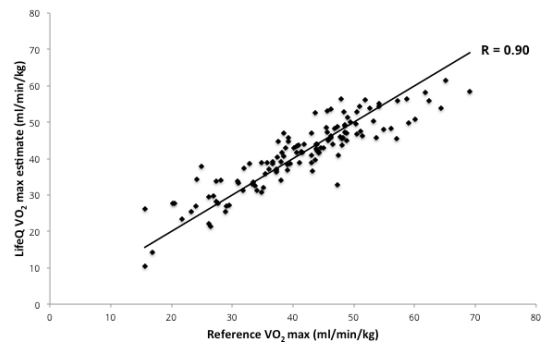


Figure 6: Scatterplot of the LifeQ estimated vs. laboratory based reference VO₂ max (ml/min/kg) values for 126 participants.

Participants were further categorized into three groups:

- uncategorized (BMI<30, non-athletes) (A)
- high BMI (BMI>30) (B) and
- athletic (C)

The MAPE across these groups are summarized in Table 1.

Table 1: Mean average percentage error distribution between predicted and reference VO₂ max values in normal, elite athlete and high BMI participants.

| | Uncategorized (A) n=74 | High BMI (B) n=32 | Athlete (C) n=16 |
|----------|---------------------------|----------------------|---------------------|
| MAPE | 6.7 | 15.9 | 9.7 |
| Rest (%) | (0.8, 5.4, 17.0)* | (0.3, 10.4, 44.9)* | (1.5, 9.7, 17.1)* |

(5th percentile, median, 95th percentile)

Conclusion

Aerobic capacity correlates strongly with life expectancy, and serves as a robust, independent indicator of cardiovascular and all-cause mortality. Aerobic capacity data can be used as a powerful tool in risk stratification and decision making in disease prevention and various clinical settings^{2,3,4,5}. The *LifeQ VO₂ max solution v2.0* provides an estimate of actual VO₂ max for better understanding of individual athletic ability,

* 5th percentile, median, 95th percentile

cardiorespiratory health and improved accuracy of other VO₂ max dependent calculated physiological parameters.

References

- ¹ Vehrs, P. R., George, J. D., Fellingham, G. W., Plowman, S. a. & Dustman-Allen, K. Submaximal Treadmill Exercise Test to Predict VO₂ max in Fit Adult. *Measurement in Physical Education and Exercise Science* 11, 61-72 (2007).
- ² Katzmarzyk PT, Church TS, Blair SN. Cardiorespiratory fitness attenuates the effects of the metabolic syndrome on all-cause and cardiovascular disease mortality in men. *Archives of Internal Medicine*. 2004;164(10):1092-1097.
- ³ Sui X, LaMonte MJ, Laditka JN, et al. Cardiorespiratory fitness and adiposity as mortality predictors in older adults. *JAMA*. 2007;298(21):2507-2516.
- ⁴ Kodama S, Saito K, Tanaka S, et al. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: A meta-analysis. *JAMA*. 2009;301(19):2024-2035.
- ⁵ Cristi-Montero C. Considerations regarding the use of metabolic equivalents when prescribing exercise for health: *Preventive medicine in practice. The Physician and sportsmedicine*. 2016;44(2):109-3.