Seismofit Validation Guide

Introduction

This guide outlines the existing evidence supporting performance claims of Seismofits, and describes necessary requirements and recommendations for conducting a thorough validation of the Seismofit system against the established CPET (Cardiopulmonary Exercise Testing) standards, in case further validation is deemed necessary.
VentriJect has already performed extensive validation of the Seismofit system, as outlined in this guide, to ensure that the Seismofit operates in compliance with the expected performance benchmarks.

This guide will provide guidelines and requirements outlining the validation procedures for assessing the Seismofit's accuracy relative to CPET.

Background:

Performance claims

Ventriject has compiled an *extensive database of over 700 Seismofit measurements with reference CPET measurements*. This database is used as the foundation for developing the algorithm, as well as validating the performance of Seismofit.

Seismofit has the following performance:

- *Seismofit is accurate*: Standard Error of the Estimate (SEE) = 5.4 ml/min/kg
- *Seismofit is reliable*: Day-to-day inter-person variations = 1.2 ml/min/kg

This performance is expected in a population above the age of 18 years, and without any of the contraindications described in the Instructions For Use [4].

If the device is used outside this intended patient group, or within patients having any of the contraindications, a worse performance might be observed.

Performance of Seismofit relative to other VO2max estimation methods

In addition to the performance measures used in these claims, other performance measures of interest are the mean absolute percentage error (MAPE) and the Pearson correlation coefficient between CPET and Seismofit.

These allow for comparing Seismofit to other VO2max estimation methods, such as the Polar fitness watch, non-exercise algorithms such as Wasserman [1] and FRIENDS [2], as well as to the Ergometer (CPET). These comparisons can be seen in Figure 1.

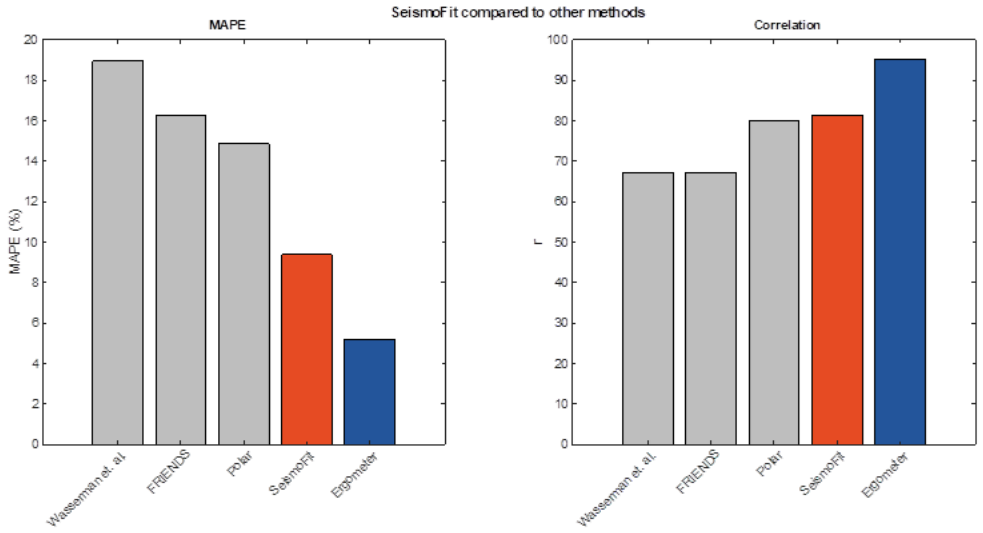


Figure 1. Seismofit® algorithm in comparison to non-exercise methods and the Ergometer in the test-set.

Algorithm	r	MAPE(%)
FRIENDS	0.672	16.2
Wasserman et. al.	0.672	19
Seismofit	0.814	9.4
Polar Watch (n=60 recordings)	0.799	14.9
Ergometer test (CPET, golden standard)	0.953	5.2

Table 1. Seismofit® algorithm in comparison to non-exercise methods in the test-set (n=109).

In 98 test-set subjects, the SCG VO2max algorithm had a correlation to CPET VO2max at r=0.87 and a mean average percentage error (MAPE) at 9.1% [3].

Existing scientific studies investigating Seismofit's performance

Extensive research has been conducted in order to validate the performance of Seismofit, see Table 2.

Table 2: Publications concerning the Seismofit® device.

Title	Study aim	N	Year	DOI
Estimation of cardiorespiratory fitness in healthy using seismocardiography	Validation of Seismofit® algorithm accuracy and repeatability	295	2025	https://doi.org/10.1038/s44325-025-00053-x
Nonexercise Estimation of V̇O2peak Using Seismocardiography in Female Subelite and Male Elite Football Players	Validation of Seismofit® algorithm accuracy and ability to detect changes over time in elite and subelite football players	112	2025	https://doi.org/10.1002/ejsc.70047
Seismocardiography as a valuable non-exercise method for estimating peak Vo2 in cardiac patients? first experiences in Germany	Explore accuracy of Seismofit® algorithm in patients with heart disease	15	2025	https://doi.org/10.1093/eurjpc/zwaf236.313
Non-exercise estimation of peak oxygen uptake in patients with ischaemic heart disease and heart failure using seismocardiography	Explore accuracy of Seismofit® algorithm in patients with heart disease	125	2025	https://doi.org/10.1093/ehjdh/ztaf095
Assessing the accuracy of Seismofit® as an estimate of preoperative maximal oxygen consumption in patients with hepato-pancreato-biliary, colorectal, and gastro-oesophageal cancer	Explore accuracy of Seismofit® algorithm in patients with cancer	33	2025	https://doi.org/10.1016/j.bjao.2025.100395
Evaluating Seismocardiography as a Non-Exercise Method for Estimating Maximal Oxygen Uptake.	Validation of Seismofit® algorithm accuracy and repeatability	94	2024	https://doi.org/10.3390/healthcare12212162
Accuracy of a non-exercise method using seismocardiography for the estimation of V̇O2peak in sub-elite football players	Accuracy of Seismofit® in sub-elite football players	47	2024	https://doi.org/10.1002/ejsc.12147
Accuracy of a vo2peak estimation at rest using	Validity and applicability	68	2024	https://www.ecss2006.com/ASP/CONG

seismocardiography before and after a 14-week lifestyle intervention in overweight and obese subjects	of Seismofit® algorithm on overweight and obese population			RESS/TOOLS/Scientific_Programme/Sessions_Abstract_Read.asp?mySessionID=OP-MH32&myAbstractID=1300
Validity and reliability of seismocardiography for the estimation of cardiorespiratory fitness.	Validity and reliability of Seismofit® algorithm	20	2023	https://doi.org/10.1016/j.cvdhj.2023.08.020
Estimation of Cardiorespiratory fitness using a using a chest mounted accelerometer	Validation of Seismofit® algorithm	300	2022	https://doi.org/10.1093/eurheartj/ehac544.2769
A Chest-Mounted Accelerometer for Estimation of Cardiorespiratory Fitness	Accuracy and reproducibility of Seismofit® algorithm	398	2022	https://doi.org/10.1016/j.cvdhj.2022.07.050
Accuracy of a Clinical Applicable Method for Prediction of VO2max Using Seismocardiography	Accuracy of Seismofit® algorithm	97	2022	https://doi.org/10.1055/a-2004-4669
Determination of Maximal Oxygen Uptake Using Seismocardiography at Rest	Accuracy of Seismofit® algorithm	97	2021	https://doi.org/10.23919/CinC53138.2021.9662756
A Clinical Method for Estimation of VO2max Using Seismocardiography	Investigate correlation between SCG and VO2max	26	2020	https://doi.org/10.1055/a-1144-3369

Requirements for Validation studies

Seismofit Measurements

The following items must be fulfilled in order for the Seismofit measurements to be satisfactory:

- The measurement must be done in accordance with the Instructions For Use (IFU), and the subjects must not have any of the contraindications mentioned in the IFU.
- The height and weight of the subject must be measured at the time of the test
- Seismofit measurements must be taken prior to CPET testing
- Subjects should be placed in a supine position and rest for at least 3 minutes prior to measurement, to attain their resting heart rate.

CPET Testing

The Seismofit has been developed based on reference data from maximum oxygen uptake (VO2max) measured using spiroergometry. The reference measurements used for validation should therefore be measured using a maximum exhaustion method, using either a bicycle ergometer or a running ergometer.

The CPET testing should be done using a calibrated system, and according to state of the art guidelines, e.g. [5-8].

The following CPET devices have been shown to have a poor accuracy [9] and should therefore not be used for validation purposes:

- PNOĒ
- VO2master

Criteria for achieving maximum oxygen uptake are:

Primary criteria:

- Plateau in oxygen uptake at increasing load

Secondary criteria:

- Respiratory Exchange Ratio (RER) > 1.1 or 1.15
- Within 5-10 beats of age-calculated max heart rate
- Secondary hyperventilation
- Perceived exertion (via 1-20 Borg scale) exceeds a value of 17

Statistical Analysis

In order to ensure an accurate estimate of the performance parameter of interest is obtained, an adequate number of measurements must be used in the validation.
To illustrate the number of samples needed, we provide an example for the 95% confidence interval of the estimated standard-error-of-estimate (SEE).
For for *n* measurements at a significance level α, the confidence interval (CI) of the root-mean-squared-error (RMSE, which in this case is equivalent to the SEE), is given as:

$$\left[\sqrt{\frac{n}{\chi^2_{1-\frac{\alpha}{2},n}}}\mathrm{RMSE}, \sqrt{\frac{n}{\chi^2_{\frac{\alpha}{2},n}}}\mathrm{RMSE}\right]$$

From this, we can plot the confidence interval as a function of the number of tests *n*, see *Figure 2*. This example aims to illustrate the necessity of having a large number of samples in order to achieve a satisfactory small confidence interval of the SEE estimate.

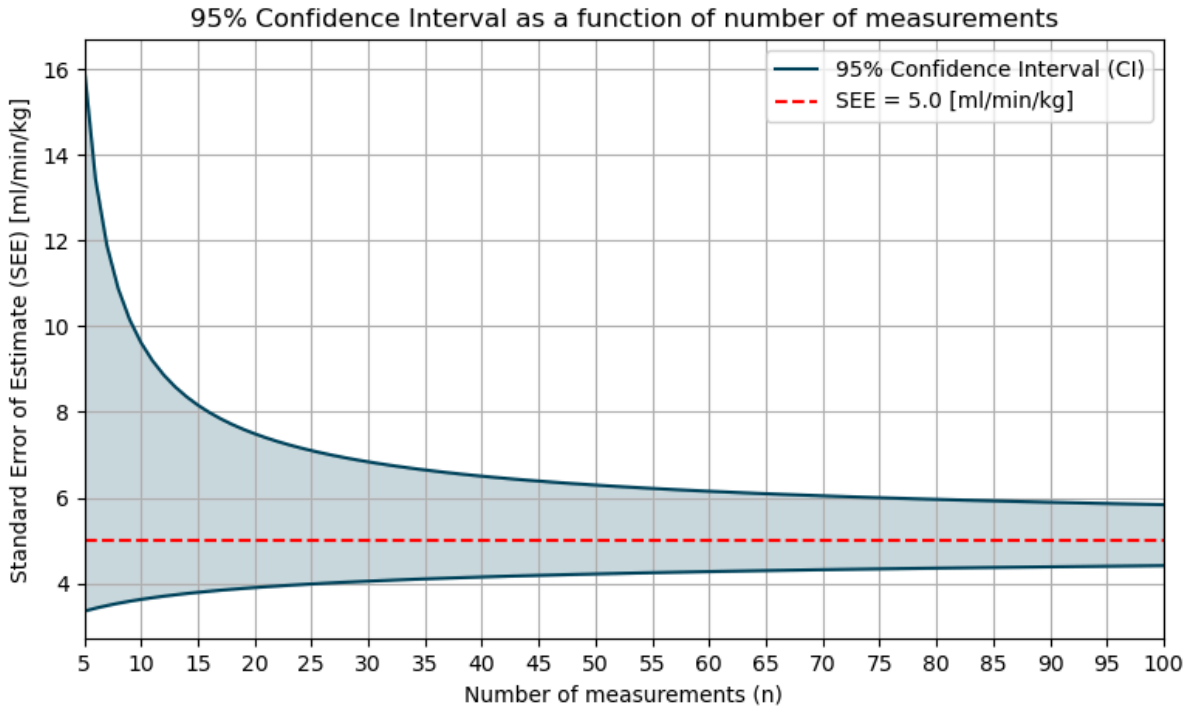


Figure 2. Confidence interval (CI) (alpha=0.05) of Standard Error of Estimate (SEE), for an assumed true SEE of 5 ml/min/kg, as a function of number of measurements.

From Figure 2, we see that as the number of samples increases, the confidence interval narrows. This demonstrates that more samples lead to a more precise estimate of the SEE.

For e.g. 5 measurements, the estimated SEE will in 95% of the cases fall somewhere between 3 ml/min/kg and 15 ml/min/kg. Any values in this range are therefore to be expected, and without more measurements, one cannot make a more precise estimate of the SEE than this. This demonstrates the importance of having sufficient measurements, when one wants to validate the Seismofit device.

As the claimed SEE of the Seismofit device is based on over 700 measurements, the confidence interval of this estimate is very low, demonstrating the high validity of the claim.

Sources

[1] Wasserman K, Hansen JE, Sue DY. No Title. Princ Exerc Test Interpret. 1994;

[2] Myers J, Kaminsky LA, Lima R, et al. A Reference Equation for Normal Standards for VO2 Max: Analysis from the Fitness Registry and the Importance of Exercise National Database (FRIEND Registry). Prog Cardiovasc Dis. 2017;60:21–29

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[4] Instructions For Use: https://ventriject.com/ifu/

[5] Levett, D Z H et al. “Perioperative cardiopulmonary exercise testing (CPET): consensus clinical guidelines on indications, organization, conduct, and physiological interpretation.” British journal of anaesthesia vol. 120,3 (2018): 484-500. doi:10.1016/j.bja.2017.10.020

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[7] Miller, M R et al. “Standardisation of spirometry.” The European respiratory journal vol. 26,2 (2005): 319-38. doi:10.1183/09031936.05.00034805

[8] Graham, Brian L et al. “Standardization of Spirometry 2019 Update. An Official American Thoracic Society and European Respiratory Society Technical Statement.” American journal of respiratory and critical care medicine vol. 200,8 (2019): e70-e88. doi:10.1164/rccm.201908-1590ST

[9] Van Hooren, Bas et al. “*Accuracy of respiratory gas variables, substrate, and energy use from 15 CPET systems during simulated and human exercise*.” Scandinavian journal of medicine & science in sports vol. 34,1 (2024): e14490. doi:10.1111/sms.14490