# Understanding z-scores in spirometry using the Vitalograph Spirotrac 6 software and ViBAC® Bacterial Viral Filter: a South African occupational health perspective

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## INTRODUCTION

Spirometry is a critical tool in occupational health (OH) for assessing lung function and diagnosing respiratory conditions. The American Thoracic Society (ATS) and the European Respiratory Society (ERS) have established guidelines for interpreting spirometry results, with the latest updates emphasising the use of z-scores. In South Africa, utilising these standards, along with tools like the Vitalograph Spirotrac 6 software used with the Vitalograph Pneumotrac 6800 Spirometer, can enhance the accuracy and relevance of spirometry in OH clinics.

## WHAT ARE Z-SCORES IN SPIROMETRY?

A z-score, also known as a standard score, indicates how many standard deviations a measurement is from the mean of a reference population. In spirometry, z-scores provide a more nuanced interpretation of lung function compared to traditional percent predicted values.

## LATEST ATS/ERS SPIROMETRY UPDATE

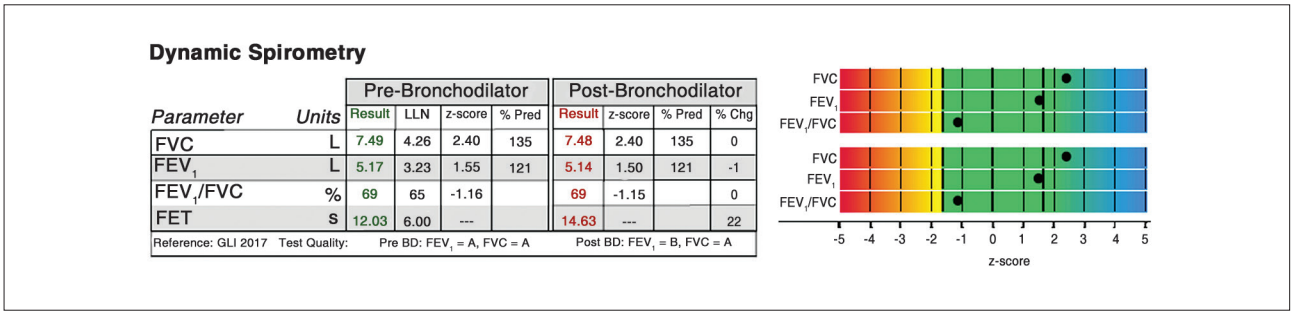
The ATS/ERS 2019 update introduced the use of the Global Lung Initiative (GLI) reference equations, which provide age, sex, height, and ethnicity-specific reference values. This is particularly relevant in South Africa, where a diverse population requires tailored reference standards for accurate spirometry interpretation.

## HOW TO INTERPRET Z-SCORES

Figure 1 shows the results of a spirometry test. z-scores are interpreted as follows:

- z-score of 0: represents the mean or average lung function for the reference population
- Negative z-scores: indicate values below the mean. For example, a z-score of -1.0 means the lung function is one standard deviation below the average
- Positive z-scores: indicate values above the mean. For example, a z-score of 1.0 means the lung function is one standard deviation above the average


**Matsobane Andries Shiburi and Xolani Marcus Mthabela demonstrating the equipment**
*Photograph: Lebogang Maseko*



**Dynamic Spirometry**

| Parameter | Units | Pre-Bronchodilator Result | LLN | z-score | % Pred | Post-Bronchodilator Result | z-score | % Pred | % Chg |
|---|---|---|---|---|---|---|---|---|---|
| FVC | L | 7.49 | 4.26 | 2.40 | 135 | 7.48 | 2.40 | 135 | 0 |
| $FEV_1$ | L | 5.17 | 3.23 | 1.55 | 121 | 5.14 | 1.50 | 121 | -1 |
| $FEV_1/FVC$ | % | 69 | 65 | -1.16 | | 69 | -1.15 | | 0 |
| FET | s | 12.03 | 6.00 | --- | | 14.63 | --- | | 22 |

Reference: GLI 2017 Test Quality: Pre BD: $FEV_1$ = A, FVC = A Post BD: $FEV_1$ = B, FVC = A



**Figure 1. Spirometry results with pre- and post-bronchodilator z-scores**

### Clinical interpretation

- Z-score between -1.64 and +1.64: considered within normal limits
- Z-score below -1.64: suggests below-average lung function, potentially indicating a restrictive or obstructive pattern, depending on other spirometry parameters
- Z-score above +1.64: suggests above-average lung function, though less common and often of less clinical concern

## USING VITALOGRAPH SPIROTRAC 6 SOFTWARE

The Vitalograph Spirotrac 6 software simplifies the collection and interpretation of spirometry data. Here's how it integrates z-scores:

### 1. Data collection

- Spirotrac 6 captures spirometry data through various tests such as forced vital capacity (FVC) and forced expiratory volume in one second ($FEV_1$).
- Forced vital capacity measures the total volume of air a person can forcibly exhale after taking the deepest breath possible.
- Forced expiratory volume in one second measures the volume of air exhaled in the first second of the FVC manoeuvre.
- Other tests include peak expiratory flow (PEF) and forced expiratory flow (FEF) 25–75%. *There are over 60 parameters on Spirotrac 6, which can be customised on both the software view and report based on your preference.*

### 2. Setting up

- Calibration: Ensure the spirometer is calibrated according to the manufacturer's guidelines. In this example, the spirometer calibration was within a 2.5% tolerance.
- Patient data entry: Enter the patient information including age, sex, height, and ethnicity to utilise the correct reference values.

### 3. Performing the test

- Preparation: Ensure the patient is seated comfortably and understands the procedure. Instruct him/her to use a nose clip to prevent air from escaping through the nose. Use a ViBAC Bacterial Viral Filter with a bacterial filtration efficiency of 99.992%, manufactured by SSEMBU for SSEM Mthembu Medical (Pty) Ltd, to ensure patient safety, end user safety, and infection control within the clinic, which reduces cross contamination.
- Environmental conditions: Conduct the test in an air-conditioned, well-ventilated room with a temperature of 21 °C, humidity of 38%, and barometric pressure of 861 hPa, as per spirometry standards.
- Execution: The patient performs the FVC manoeuvre, exhaling forcefully into the spirometer as coached by the end user. Repeat the test at a minimum of three efforts and a maximum of eight efforts to ensure reproducibility. In the example in Figure 2, the patient performed four efforts, with one effort invalidated and deleted by the end user due to a detected cough, due to usability error.

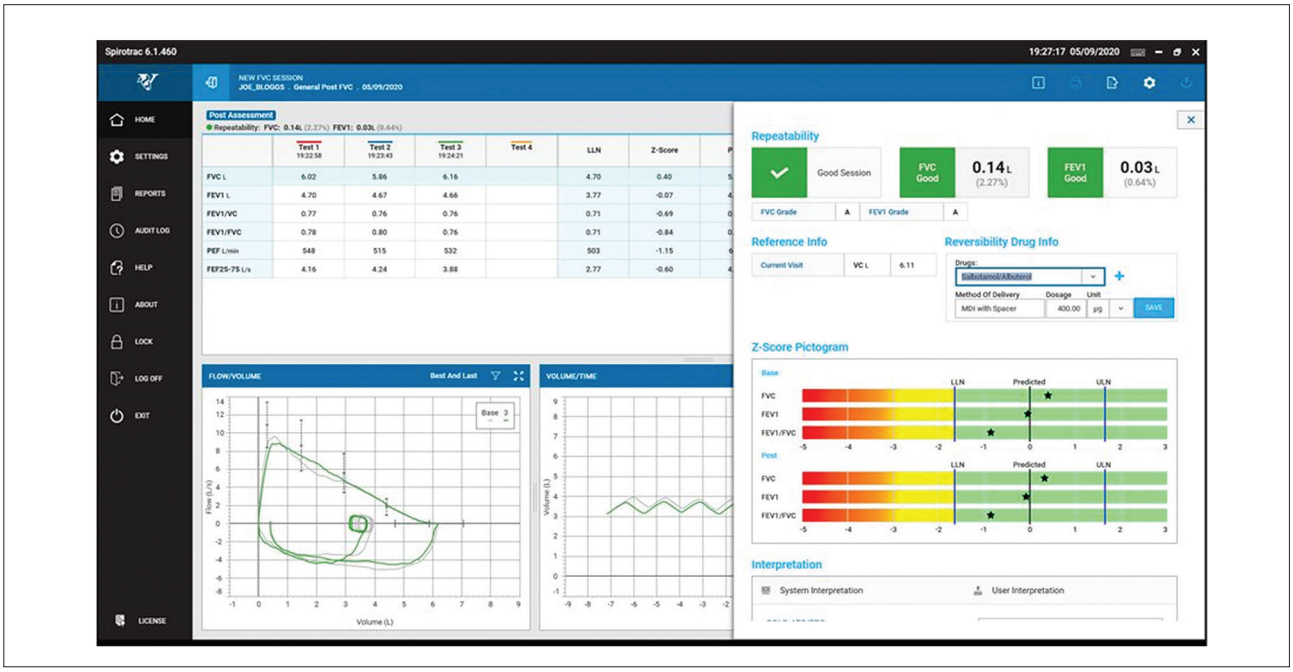



**Figure 2. Spirotrac 6 software testing and results window**

### 4. Data capture and analysis

- Recording: Spirotrac 6 captures and records the test results, displaying real-time flow-volume and volume-time curves.
- Automated calculations: The software automatically calculates key parameters like FVC, $FEV_1$, PEF, FEF 25–75%, and more.

### 5. Interpreting z-scores

- GLI reference equations: Spirotrac 6 uses GLI reference values, which are tailored for diverse populations, including those in South Africa.
- Z-score calculation: The software provides z-scores for each parameter, indicating how the patient's results compare to the reference population.

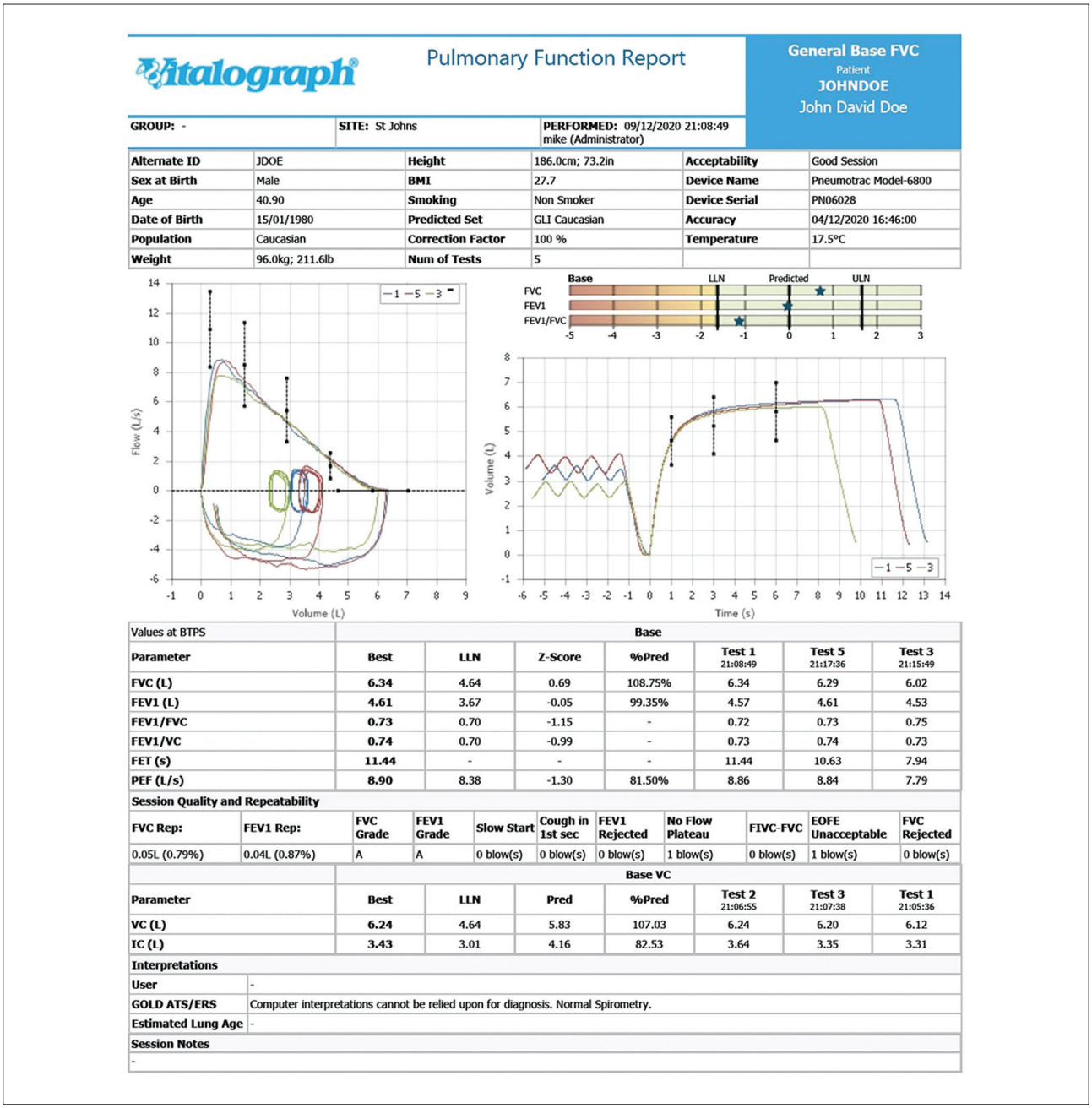
### 6. Generating reports

As shown in Figure 3, Spirotrac 6 generates comprehensive and detailed reports that include spirometry results, z-scores, and interpretive comments. The reports can be customised to highlight critical findings and recommendations for follow-up or further testing.

## PRACTICAL APPLICATION IN SOUTH AFRICAN OH CLINICS

Using Spirotrac 6 in a South African OH setting involves the following steps:

1. Baseline or pre-testing: Establish baseline lung function for new employees to identify pre-existing conditions and ensure they are fit for their roles.
2. Periodic monitoring: Conduct regular spirometry tests to monitor any changes in lung function, particularly for workers exposed to respiratory hazards.
3. Interpreting results: Use z-scores to detect early signs of occupational lung diseases, enabling timely interventions.
4. Documentation and follow-up: Maintain detailed records of all spirometry tests and follow up with any workers showing abnormal results, for further evaluation and management.



Vitalograph

**Pulmonary Function Report**

**General Base FVC**
Patient
**JOHNDOE**
John David Doe

**GROUP:** - **SITE:** St Johns **PERFORMED:** 09/12/2020 21:08:49 mike (Administrator)

| | | | | | |
|---|---|---|---|---|---|
| **Alternate ID** | JDOE | **Height** | 186.0cm; 73.2in | **Acceptability** | Good Session |
| **Sex at Birth** | Male | **BMI** | 27.7 | **Device Name** | Pneumotrac Model-6800 |
| **Age** | 40.90 | **Smoking** | Non Smoker | **Device Serial** | PN06028 |
| **Date of Birth** | 15/01/1980 | **Predicted Set** | GLI Caucasian | **Accuracy** | 04/12/2020 16:46:00 |
| **Population** | Caucasian | **Correction Factor** | 100 % | **Temperature** | 17.5°C |
| **Weight** | 96.0kg; 211.6lb | **Num of Tests** | 5 | | |



| Values at BTPS | Base | | | | | | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **Best** | **LLN** | **Z-Score** | **%Pred** | **Test 1** 21:08:49 | **Test 5** 21:17:36 | **Test 3** 21:15:49 |
| **FVC (L)** | **6.34** | 4.64 | 0.69 | 108.75% | 6.34 | 6.29 | 6.02 |
| **FEV1 (L)** | **4.61** | 3.67 | -0.05 | 99.35% | 4.57 | 4.61 | 4.53 |
| **FEV1/FVC** | **0.73** | 0.70 | -1.15 | - | 0.72 | 0.73 | 0.75 |
| **FEV1/VC** | **0.74** | 0.70 | -0.99 | - | 0.73 | 0.74 | 0.73 |
| **FET (s)** | **11.44** | - | - | - | 11.44 | 10.63 | 7.94 |
| **PEF (L/s)** | **8.90** | 8.38 | -1.30 | 81.50% | 8.86 | 8.84 | 7.79 |

**Session Quality and Repeatability**

| **FVC Rep:** | **FEV1 Rep:** | **FVC Grade** | **FEV1 Grade** | **Slow Start** | **Cough in 1st sec** | **FEV1 Rejected** | **No Flow Plateau** | **FIVC-FVC** | **EOFE Unacceptable** | **FVC Rejected** |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.05L (0.79%) | 0.04L (0.87%) | A | A | 0 blow(s) | 0 blow(s) | 0 blow(s) | 1 blow(s) | 0 blow(s) | 1 blow(s) | 0 blow(s) |

| | Base VC | | | | | | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **Best** | **LLN** | **Pred** | **%Pred** | **Test 2** 21:06:55 | **Test 3** 21:07:38 | **Test 1** 21:05:36 |
| **VC (L)** | **6.24** | 4.64 | 5.83 | 107.03 | 6.24 | 6.20 | 6.12 |
| **IC (L)** | **3.43** | 3.01 | 4.16 | 82.53 | 3.64 | 3.35 | 3.31 |

| **Interpretations** | |
|---|---|
| **User** | - |
| **GOLD ATS/ERS** | Computer interpretations cannot be relied upon for diagnosis. Normal Spirometry. |
| **Estimated Lung Age** | - |
| **Session Notes** | |
| - | |

**Figure 3. Spirometry final report generated by Spirotrac 6 software**

## EXAMPLE CASE STUDY

### Patient profile

- Age: 35 years
- Sex: Male
- Ethnicity: Non-Caucasian
- Height: 170 cm
- Weight: 69 kg
- Occupation: Miner in Rustenburg
- Test: Pre-bronchodilator spirometry

### Environmental conditions

- Room Temperature: 21 °C
- Humidity: 38%
- Barometric Pressure: 861 hPa
- Filter used: ViBAC Bacterial Viral Filter with 99.992% bacterial filtration efficiency (BFE)

### Spirometry results

- FVC: 3.5 L (predicted: 4.0 L)
- $FEV_1$: 2.8 L (predicted: 3.6 L)
- $FEV_1$/FVC ratio: 0.8 (predicted: 0.9)
- Efforts: 4 (one effort deleted due to cough detection by Spirotrac 6)

### Interpretation using z-scores

***1. FVC z-score:***

- Reference FVC for a non-Caucasian male of height 170 cm: 4.0 L
- Measured FVC: 3.5 L
- Standard deviation (SD) for FVC: 0.5 L
- z-score calculation: (3.5–4.0)/0.5 = -1.0

***2. FEV1 z-score:***

- Reference $FEV_1$ for a non-Caucasian male of height 170 cm: 3.6 L
- Measured $FEV_1$: 2.8 L
- Standard deviation (SD) for $FEV_1$: 0.4 L
- z-score calculation: (2.8–3.6)/0.4 = -2.0

***3. FEV1/FVC ratio:***

- Reference $FEV_1$/FVC ratio: 0.9
- Measured ratio: 0.8
- Interpretation: ratio is within the lower limit of normal, indicating a mild obstruction

### Clinical interpretation

- The FVC z-score of -1.0 is within normal limits.
- The $FEV_1$ z-score of -2.0 indicates below-average lung function, suggesting mild obstruction.
- The $FEV_1$/FVC ratio further supports the presence of an obstructive pattern.

### Recommendations

- The patient shows mild pulmonary obstruction, which may affect his ability to work in the underground mining environment.
- A detailed pulmonary evaluation and consideration of occupational adjustments to prevent further respiratory compromise is recommended.
- Regular spirometry monitoring is advised to track any changes in lung function.

## CONCLUSION

The Vitalograph Spirotrac 6 software, integrated with z-scores and aligned with the latest ATS/ERS guidelines and GLI reference values, emerges as an indispensable asset for OH professionals in South Africa. This advanced tool not only ensures precise and standardised spirometry testing, but also empowers clinicians to detect early signs of respiratory issues, guide targeted interventions, and ultimately safeguard the respiratory health of workers in diverse occupational environments. Its contribution extends beyond diagnostics, serving as a cornerstone in promoting a culture of proactive respiratory care within the workplace.

*Disclaimer: The information provided in this article is intended for informational purposes only. It is not a substitute for professional medical advice, diagnosis, or treatment. Readers are advised to consult qualified healthcare professionals.*

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