



Innovation in Spirometry Oximetry Telemedicine

LLN and Z-SCORE: Standard Deviation

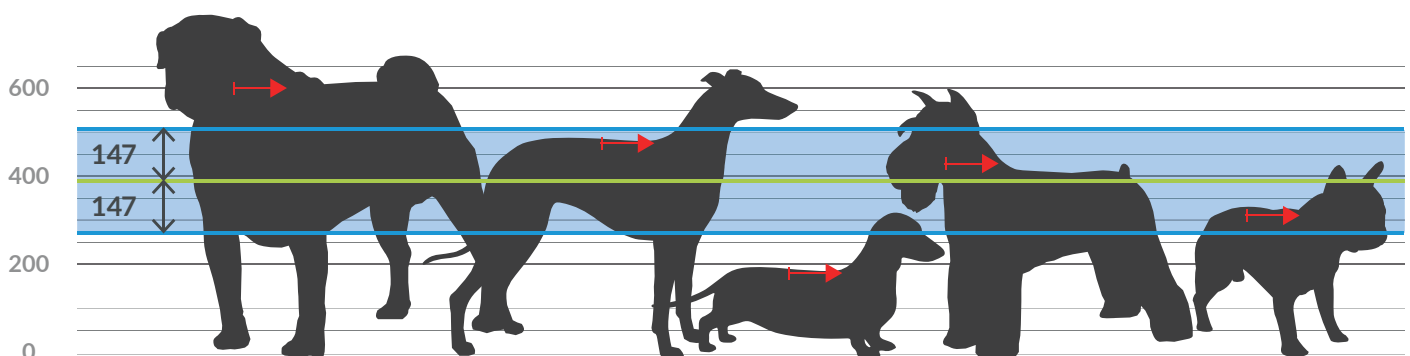
To define the LLN and the Z-Score is necessary to introduce the concept of **STANDARD DEVIATION**:

SD

The **STANDARD DEVIATION (SD)**
“is a measure of how spread out numbers are from their **EXPECTED MEAN VALUE**”

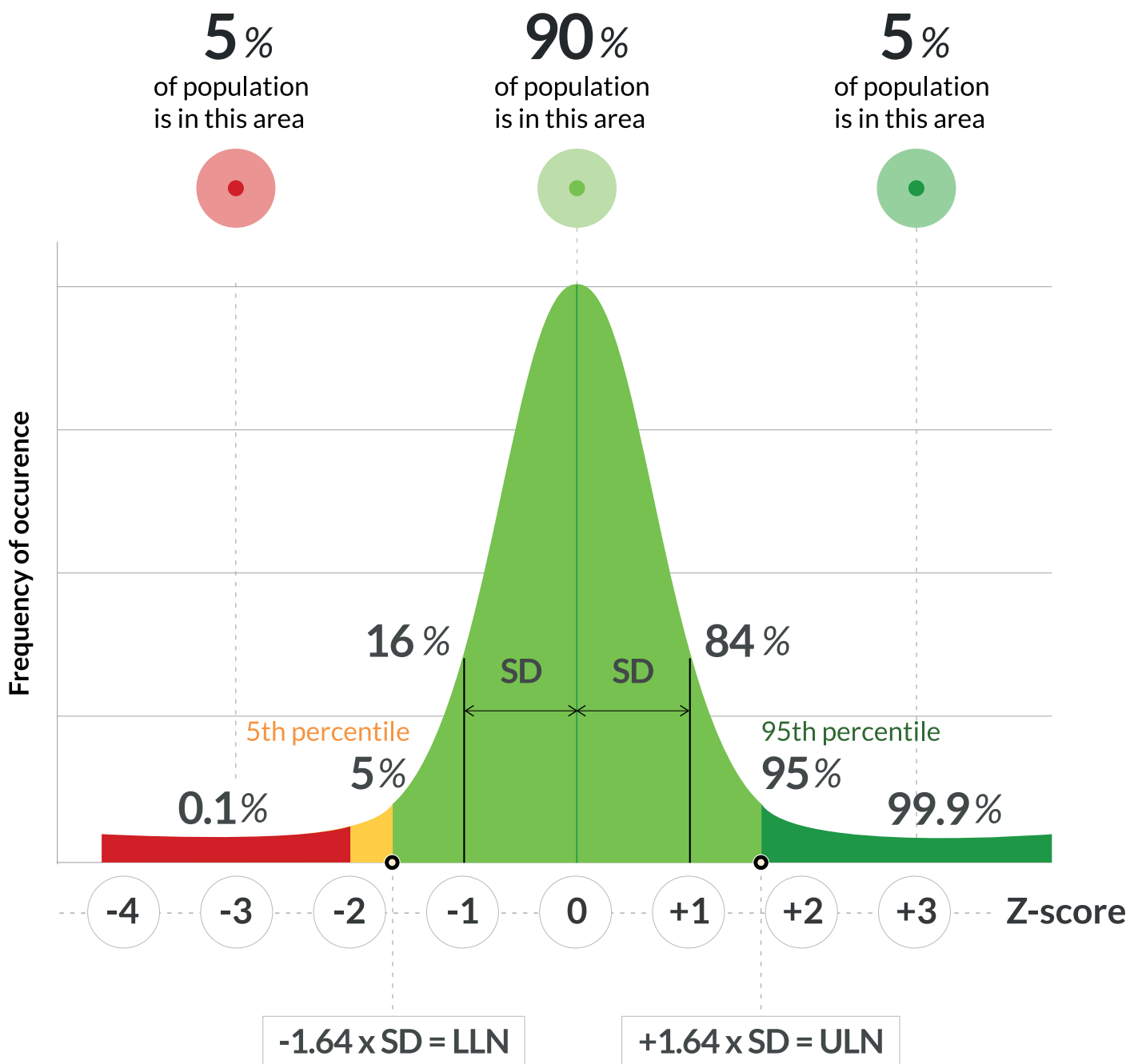
”

The heights of dogs at the shoulders in millimeters



In case of dogs, using the **STANDARD DEVIATION** we have a “standard” way of knowing what is **normal** (Schnauzer), and what is **extra large** (Rottweiler) or **extra small** (Dachshund).

LLN and Z-SCORE: Standard Deviation



The central line is the position of the **MEAN** value

- 50% of population is above this value
- 50% is below this value

Normal Distribution and Percentile

When the data tend to be around a central value we have a **NORMAL DISTRIBUTION** with a bell-shaped curve.

Relationship between **STANDARD DEVIATION (SD)** and percentage of data under the curve in the case of a normal distribution.

When the data tend to be around a central value we have a **NORMAL DISTRIBUTION** with a bell-shaped curve.

68% of measures are between **+1 and -1**
STANDARD DEVIATION

90% of measures are between **+1.64 and -1.64**
STANDARD DEVIATION

Location and meaning of the 5th percentile

The range between the 5th percentile and 95th percentile includes 90% of the population.

The 5th percentile (**-1.64 STANDARD DEVIATION**) is the minimum value of the observed parameter below which is only 5% of the population.

LLN and Z-SCORE: Standard Deviation



Predicted LLN and Z-Score

Results of spirometric tests characteristically lead to values for FVC and FEV1 which are too low rather than too high in disease.

This explains why the LLN is defined as that value which identifies the lower 5th percentile of a healthy population of non-smokers.

If a patient has an FEV1 MEASURED = LLN,
it means that he is at the limit of the 5th percentile.
Only 5% of the healthy population, with his own anthropometric data, has a lower value.

Therefore 5% of the healthy population represents false positives, ie healthy subjects having values **below the LLN** and then, at first sight, could be considered sick!

There are two methods of comparison MEASURED vs PREDICTED.

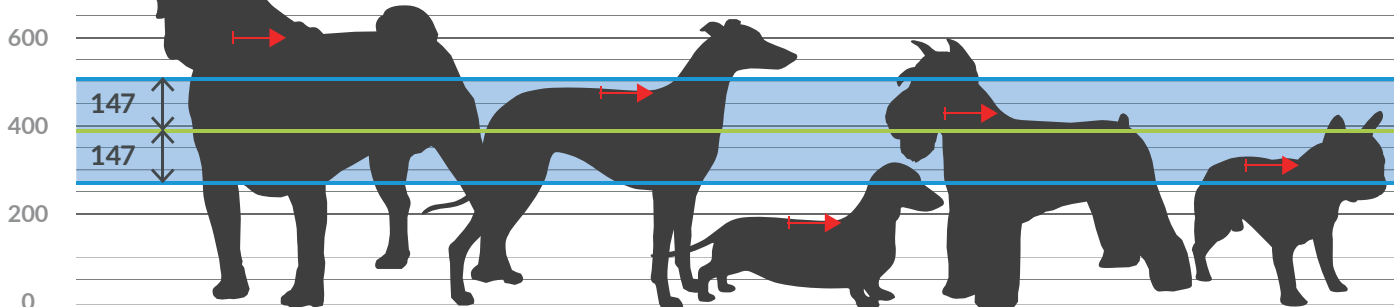
**1) CLASSIC: %PREDICTED =
MEASURED / PREDICTED x 100**

**2) NEW: Z-SCORE =
(MEASURED - PREDICTED) / STANDARD DEVIATION**

In the dogs example, for simplifying we assume that the PREDICTED value of the height is equal to the MEAN value.

How to use the Standard Deviation

The heights of the dogs (in mm) are: 600, 470, 170, 430 and 300

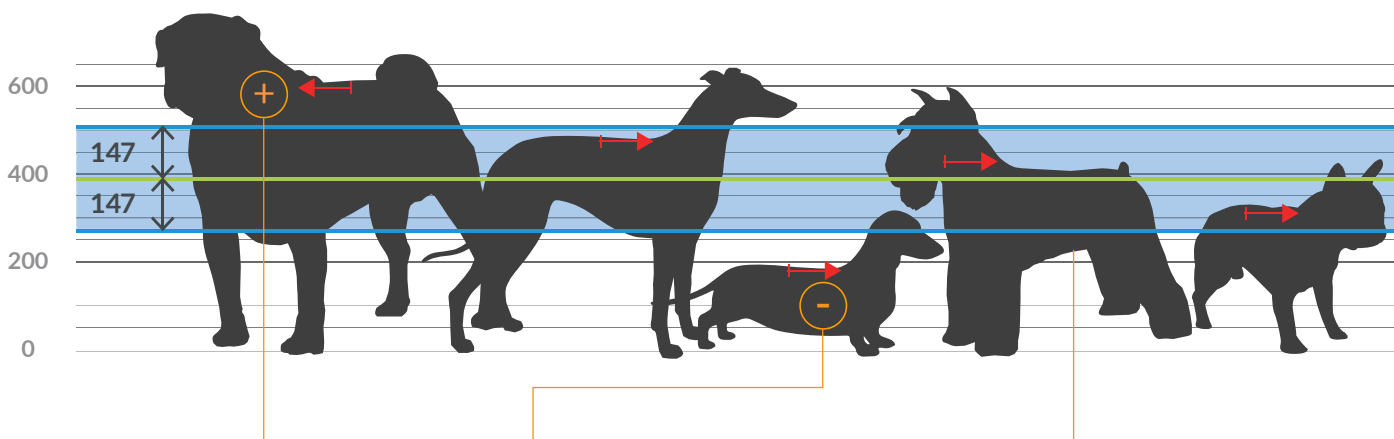


MEAN = 394 mm (green line)

STANDARD DEVIATION = 147 mm (blue line)

LLN = MEAN - 1.64 x STANDARD DEVIATION = 394 - 1.64 x 147 = 153

NOTE: the **STANDARD DEVIATION** is calculated by taking in account the differences between the **MEASURED VALUE** and the **MEAN VALUE** for all dogs.

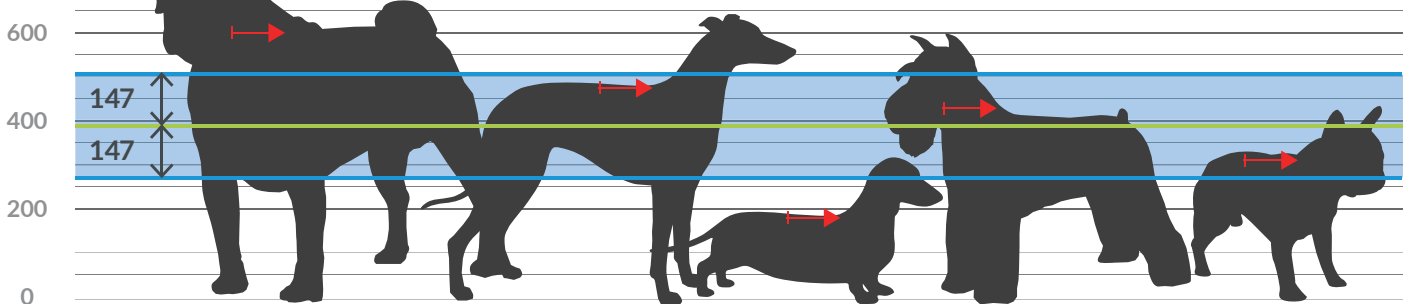


Rottweiler (+) and Dachshund (-) are both of them more than 1 **STANDARD DEVIATION** over the **MEAN VALUE**.

Schnauzer is very close to the green line and so it is less than 1 **STANDARD DEVIATION** from the **MEAN VALUE**

Let's try to calculate %Predicted and Z-Score

The heights of the dogs (in mm) are: 600, 470, 170, 430 and 300



CLASSIC METHOD: %PREDICTED = MEASURED / PREDICTED x 100

Rottweiler $600/394 \times 100 = 152\%$ taller then **PREDICTED**

Dachshund $170/394 \times 100 = 43\%$ shorter then **PREDICTED**

Schnauzer $430/394 \times 100 = 109\%$ very close to **PREDICTED**

It is a very intuitive method and indicates what is the percentage value of the **MEASURED VALUE** in relation to the **PREDICTED VALUE**.

NEW METHOD: Z-SCORE = (MEASURED - PREDICTED) / STANDARD DEVIATION

Rottweiler $(600-394)/147 = +1.40$ = more then 1 SD taller

Dachshund $(170-394)/147 = -1.52$ = more then 1 SD shorter

Schnauzer $(430-394)/147 = +0.24$ = less then 1 SD taller

This method is less intuitive and indicates how often a measurement is greater (+) or less (-) of the **STANDARD DEVIATION**.

LLN and Z-SCORE: Standard Deviation



The benefits of Z-Score

The LLN value can also be expressed as a percentage of the PREDICTED:

- 1) In a healthy person, 20 years old: **LLN of FEV1 = 80% of his PREDICTED**
- 2) In a healthy person, 80 years old: **LLN of FEV1 = 66% of his PREDICTED**

It is clear that the true LLN, when expressed as %PREDICTED, varies considerably with the age. FEV1 value of 66% of the PREDICTED may be fine in a 80 years old person but it would be abnormal for a 20 years old person!

Therefore evaluate a respiratory disease according to the calculation method% PREDICTED is a very popular but should be replaced by the method of the Z-SCORE.

The benefit is that Z-SCORE is completely independent of age, height and sex.

For example, if the Z-SCORE for any parameter is -1.64, this signifies in males, females, children and adults that the measured value is at the 5th percentile.

In lung function testing this is regarded as the LLN.

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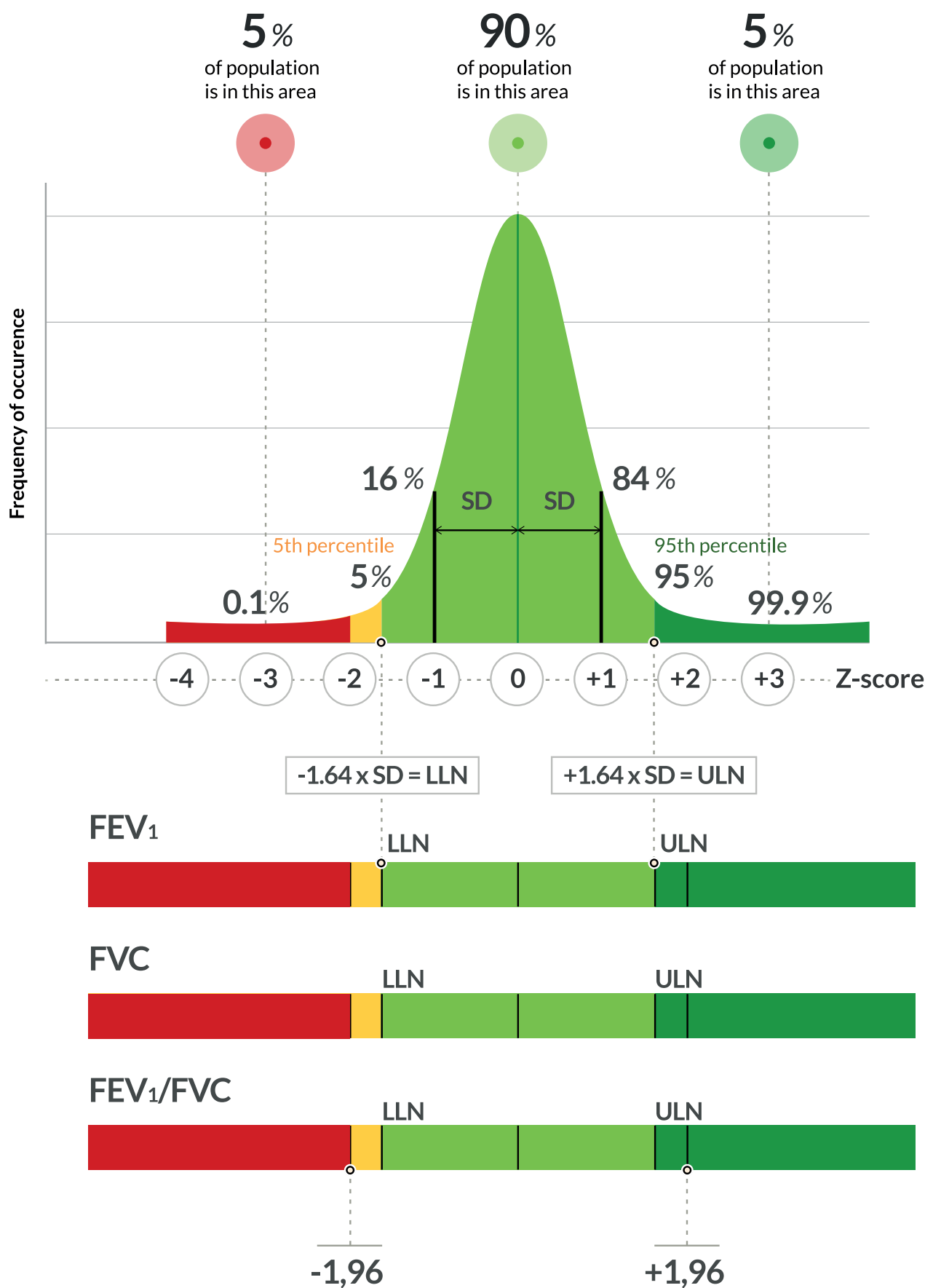
Interpretation of Spirometric results

When interpreting test results there is uncertainty about the “abnormality” of a finding near the LLN than if the test result is within the normal range or in a pathological range.

*Measured values of **FEV1**, **FVC**, **FEV1/FVC** with additional indices, such as PRE and POST bronchodilator, predicted values, **LLN**, % of predicted, confuses most users.*

*Conversely, **PICTOGRAMS** in which **Z-SCORE** are depicted relative to a normal range allow a simple interpretation of the spirometric results.*

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Interpretation of Spirometric results

When Z-SCORE is -1.64, it means that the parameter of the spirometry is placed exactly on the LLN that represents the point below which only 5% (5th percentile) of the normal population had a value lower than predicted.

In the center of **PICTOGRAM** the **Z-SCORE** is equal to 0, it indicates that the measured value is exactly equal to the predicted one.

In this point we find 50% of the healthy population (the center of the bell).

In conclusion, If a patient has an **FEV1 MEASURED = LLN**, it means that he is at the limit of the 5th percentile.

Only 5% of the healthy population, with his own anthropometric data, has a lower value.

In short, it is still healthy but he is very close to...
...the population considered sick!





www.spirometry.com
www.mirsmartone.com

ITALY

MIR Head Office

Via del Maggiolino, 125
00155 Roma

Phone +39 06 22 754 777
Fax +39 06 22 754 785

mir@spirometry.com

USA

MIR USA, Inc.

5462 S. Westridge Drive
New Berlin, WI 53151

Phone +1 (262) 565 - 6797
Fax +1 (262) 364 - 2030

mirusa@spirometry.com

FRANCIA

MIR Local Office

Jardin des Entreprises,
290, Chemin de Saint Dionisy
30980 LANGLADE (France)

Phone +33 (0) 4 66 37 20 68
Fax +33 (0) 4 84 25 14 32

mirfrance@spirometry.com