BTPS Correction for Flow and Volume

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1. Introduction

BTPS correction is used to convert flow and volume measured at ambient conditions to the conditions within the lungs. Ambient conditions are called ATPH (**A**mbient **T**emperature, ambient barometric **P**ressure, ambient relative **H**umidity); the conditions within the lungs are called BTPS (**B**ody **T**emperature, ambient barometric **P**ressure, **S**aturated with water vapor). BTPS correction therefore compensates for changes in gas volume due to changes in temperature, pressure, and humidity. BTPS correction does not adjust incorrect measurements of the flow sensor, but it compensates physical effects like the ideal gas law.

1.1 Background

BTPS correction is different for inspiratory and expiratory flow and volume measurements:

Expiratory air coming out of the lungs is saturated with water vapor and almost at body temperature. The small difference between the lung temperature and the temperature of the air within the flow sensor is usually corrected with a fixed BTPS correction factor of 2%. This assumes that exhaled air is cooled down to approx. 34°C when it reaches the flow sensor (see [1]).

Inspiratory flow and volume are measured at ambient conditions and must be converted to lung conditions (BTPS). In this case the conversion is performed using the formula shown below (see supplement of [2]).

$$\frac{V_{BTPS}}{V_{ATPH}} = \frac{T_{body}}{T_{amb}} \cdot \frac{P_{amb} - P_{H2O}(T_{amb}, H_{amb})}{P_{amb} - P_{H2O}(T_{body}, H_{body})}$$

V_{BTPS} represents the volume at BTPS conditions; V_{ATPH} the volume at ATPH conditions; P_{amb} the ambient pressure; P_{H2O} the partial pressure of water vapor at a given temperature and humidity; T_{amb} and T_{body} ambient and body temperature (in Kelvin); H_{amb} and H_{body} the relative humidity of ambient air and of the air within the lungs.

The BTPS correction factor is calculated using the following information provided by the user or measured by sensors: ambient temperature, ambient humidity, and ambient pressure. If an ambient pressure sensor is not available, altitude is converted to an approximate pressure value using the following formula (see [2]):

$$P_{amb} = P_0 \cdot (1 - 2.25577 \cdot 10^{-5} \cdot h)^{5.25588}$$

The pressure P_{amb} at altitude h is calculated using the reference pressure P_0 (1013 hPa) and the altitude h in meters.

The following table lists some examples of BTPS correction factors. Please note that a BTPS correction factor of 1.12 corresponds to a correction of 12%.

Ambient Temperature in °C	Ambient Pressure in hPa	Ambient Humidity in %	Body Temperature in °C	BTPS Correction Factor	Remarks
20	1013	50%	37	1.115	Normal conditions at sea level
20	898	50%	37	1.123	Normal conditions at 1000 m
20	1013	30%	37	1.121	Low humidity at sea level
37	1013	50%	37	1.033	High temperature
37	1013	100%	37	1.000	High temperature and humidity
20	616	20%	37	1.170	Altitude of 4000 m

It is easy to see that the correction factor is approx. 12% for normal conditions. An altitude change of 1000 m changes the BTPS correction factor only by 0.7%. If temperature and humidity are high the correction factor decreases. If the temperature of the inhaled air and the degree of humidity correspond to lung conditions, no correction needs to be applied (correction factor 1.0). At high altitude, low temperature, and low humidity the correction factor can be very high, as in the example shown above.

2. References

[1] Madan I, Bright P, Miller MR. Expired air temperature at the mouth during a maximal forced expiratory manoeuvre. *Eur Respir J* 1993;6(10):1556–1562.

[2] Graham BL, Steenbruggen I, Miller MR, et al. Standardization of Spirometry 2019 Update. *Am J Respir Crit Care Med* 2019;200(8):e70–e88.