New Quark RMR validation with ethanol burning kit

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Purpose
Validate the Quark RMR with the ethanol burning kit system.

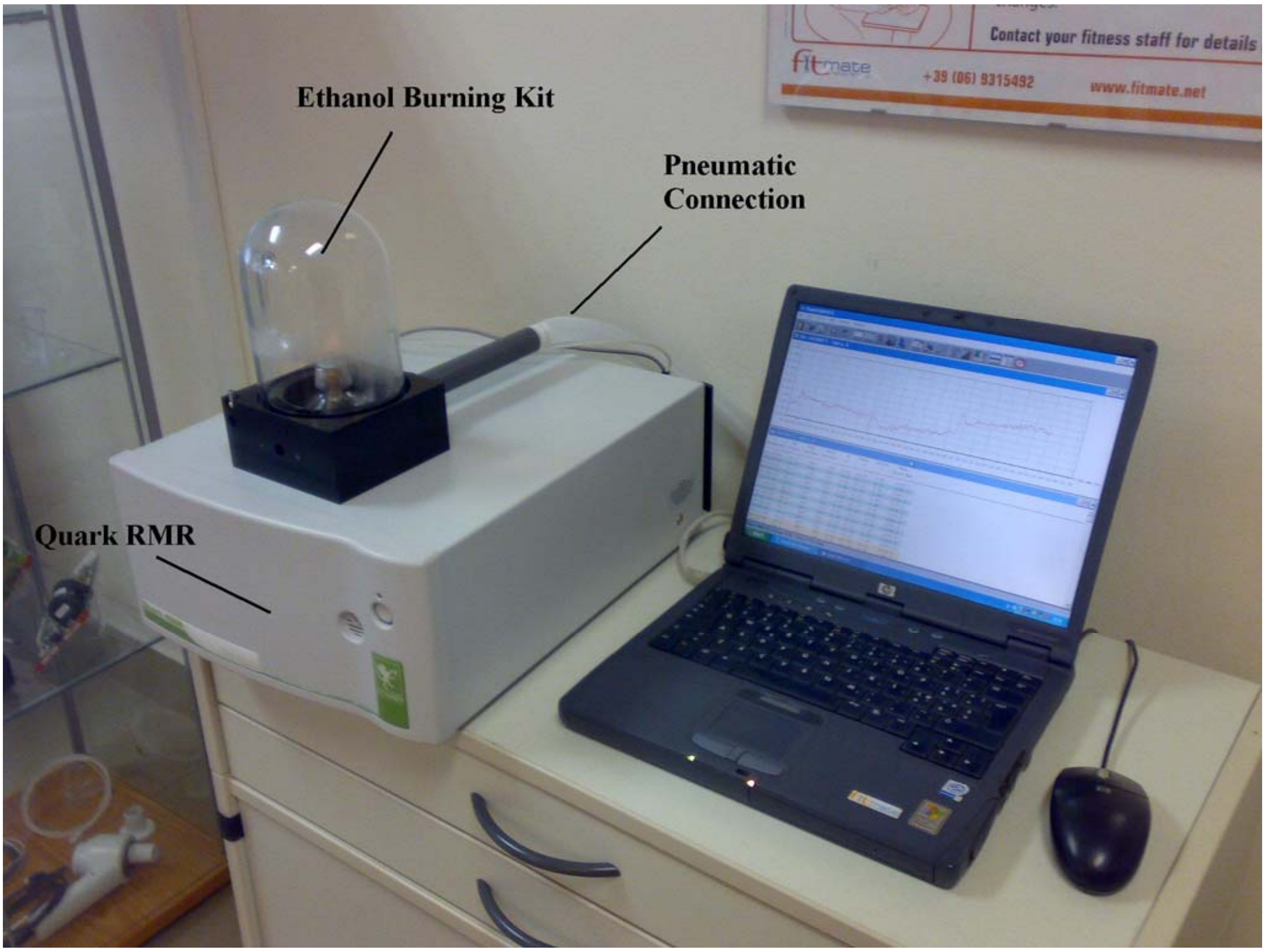
RQ simulation
Indirect Calorimetry by the gas-exchange method in the spontaneously breathing or mechanically ventilated subject is an exacting process that challenges the accuracy and error sensitivity of the measuring instrumentation.
Several in vitro techniques, vary in complexity and difficulty of constructions, have been described in the literature for the validation of the devices used in Indirect Calorimetry field.
Solvent-burning lung models have been an attractive validation method because of their apparent simplicity and the availability of high-purity fuels that have predictable respiratory quotient values.
When completely and properly burned, the fuel consume only O_2, and combustion by-products contain only water vapor and carbon dioxide (CO_2).
However, predictable and adjustable rates of O_2 consumption (VO_2) and CO_2 production (VCO_2) are difficult to achieve with this type of model, and during the trials the operator has to check all the variables involved in the measurement in order to achieve good results.
RQ alone, which is the aim of our validation, is flow independent and can easily be validated by burning ethanol in a system with a proper gas collection configuration.
For ethanol, the stoichiometric equation is:

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

The stoichiometric equation describes the quantitative VO2, VCO2, and production of water as products of combustion. The ratio of VCO2 to VO2 in the burning of ethanol yields an RQ of 0.667.
There are several techniques in performing the alcohol burning test.
First of all, the liquid can be burned either in an open vessel or in a lamp with a wick; in our tests we noted that ethanol burned in a lamp with a non-combustible wick is the best solution to avoid differences in VO2 and VCO2 during the test and maintain high-purity fuels.
In a vessel the differences in the surface available to burn during the test modifies the values of oxygen consumption after few minutes from test beginning.
The reaction rate, an hence the fuel-consumption rate, is determined by the O_2 available to the flame, the fuel flow to the burning region, temperature, and combustion product clearance.
In our conventional ethanol burning kit, these parameters are difficult to control and equally difficult to sustain over the course of a gas-exchange measurement run.
Although the RQ should not vary in the model we used, the burn rate invariably does.
Unfortunately in a wick-based ethanol-burning models many factors must be control to achieve a stable and repeatable VO2 and VCO2; changes in ventilation , FiO_2, and fuel level will have an effect on the fuel consumption rate.
Reproducing a given wick geometry from one session to the next is difficult as well.

Because CO_2 is heavier than either component of air, stratification of the internal atmospheric environment of the model can change the FiO_2 presented to the flame and alter its fuel-consumption rate.
Under certain conditions, this process may starve the flame foe O_2 and begin produced unwanted CO before extinguished the flame; in some trials this happened before complete the session of measurement.
Since our aim was to evaluate the correct measures of RQ , we didn't care about VO2 and VCO2 measures but our attention was only towards the RQ value during the test.

Measurement setup and methods



Materials used for the tests:

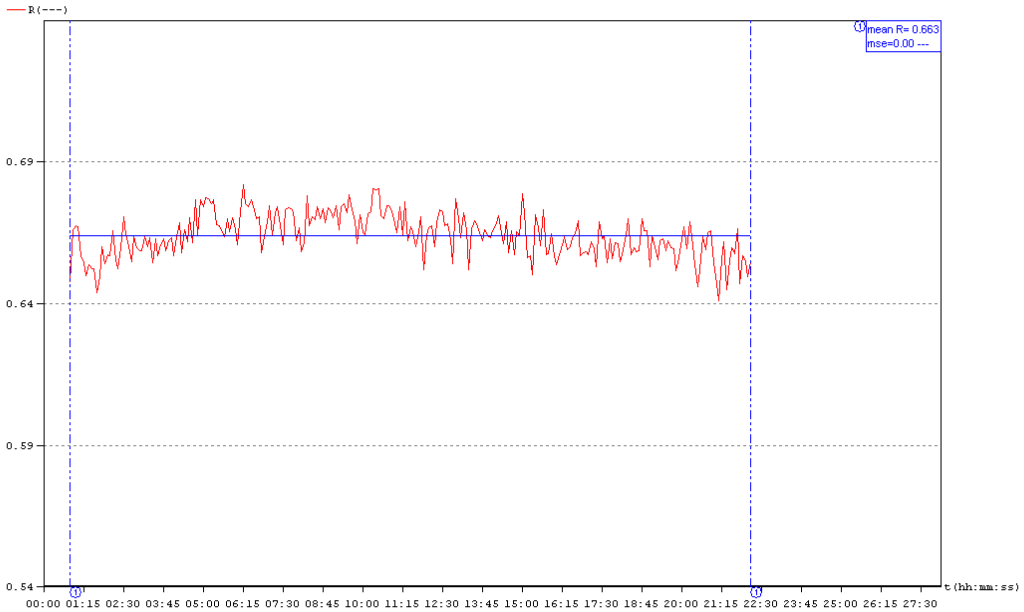
- Alcohol burning kit (burner base, alcohol burner with wick and glass cover)
- Canopy blower and its pneumatic connection
- Quark RMR with its optoelectronic reader (Turbine) and sampling line (Permapure)
- Calibration Cylinder with concentration of O_2=16,00 and CO_2=5,00

All the equipment used during the test were assembled as shown in the pictures above.
Before each test, a gas calibration was performed in order to assure a correct measurement during the test.
Canopy tube was connected to the alcohol burning kit by means of a rigid plastic tube to prevent fire problem in case of wrong regulation of the flame.

Trials have been made in ventilated atmosphere.
All the connections among Canopy and Quark RMR and Alcohol burning kit have been made in the same manner the operator would connect them during a test with Canopy and its hood.

Results

Duration	22m30s
Average Ventilation	43.85 l
Average $FeCO_2$	0.65
Average FeO_2	19.95
Average RQ	**0.663**



Results above demonstrate that, although it is not simple to perform a correct burning test considering all the variables that can affect its correctness, the Canopy system measures a right values of 0.663 instead of the 0.667 expected (acceptable range is from 0.64 up to 0.69).

References

1.**Miodownik, Saul, Jose Melendez, Vittoria Arslan Carlon, and Brian Burda.** Quantitative methanol-burning lung model for validating gas-exchange measurements over wide range of F_{IO2}. *J.Appl.Physiol. 84(6):2177-2182, 1998.*

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