Indirect calorimetry in canopy mode in healthy subjects: performances of the Q-NRG device compared to the Deltatrac II

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Abstract

Background: **Extensive validation of the Q-NRG indirect calorimeter in canopy mode, especially against reference devices, is lacking. The aim of this study was to test its agreement in canopy mode with the Deltratrac II, which has always been considered as the gold standard indirect calorimeter in daily practice.**

Methods: **Healthy volunteers underwent indirect calorimetry with two consecutive assessments, using Q-NRG and Deltatrac II, both in canopy mode, in a random order, after careful calibrations. Body position, fasting conditions and environment were standardized. Agreement between the two devices was evaluated by paired Student's t test, correlation coefficients, and Bland-Altman plots.**

Results: **Sixty-one adults (85.2% male, aged 25.7±8.4 y, BMI 23.3±2.9 kg/m²) were included. Measured energy expenditure was similar whether it was measured using Q-NRG or Deltatrac II: 1816±361 kcal/day or 1809±260 kcal/day (p=0.803), respectively. There was a significant positive correlation between the two measures (ρ=0.78, p= <0.01). The Q-NRG slightly overestimated the energy expenditure compared to the Deltatrac II measure: the bias ± limits of agreement was 7 ± 227 kcal/day.**

Conclusion: **In healthy volunteers breathing spontaneously, the Q-NRG in canopy mode performed similarly to the Deltatrac II for energy expenditure measurement. The present study confirms the previously demonstrated accuracy of the Q-NRG device, and supports its clinical use in canopy mode. (**Acta gastroenterol belg., **2025**, 88, **13-17**).

Keywords: indirect calorimetry, canopy, energy expenditure, nutrition.

Background

Indirect calorimetry (IC) is the most practical method for energy expenditure (EE) measurement in clinical settings. By measuring the inspired and expired oxygen and carbon dioxide concentrations as well as the volume of expired gas, indirect calorimeters measure the oxygen consumption rate ($\Delta \mathring{V}O_2$) and the carbon dioxide production rate ($\Delta \mathring{V}CO_2$). Biological fuels (glucose, free fatty acids and amino acids) are oxidized, while producing CO_2, water, heat and adenosine triphosphate. EE can thus be derived from the $\Delta \mathring{V}O_2$ and $\Delta \mathring{V}CO_2$, using the modified Weir formula. The basal EE measurement is performed in a resting state that is free of physical and psychological stress, a thermally neutral environment, and a fasting state requiring a minimum 10-hour delay between measurement and last nutritional intakes (1). After energy intakes, the diet-induced thermogenesis is added to the basal EE, corresponding to the resting EE. The respiratory quotient (RQ), the ratio of $\Delta \mathring{V}CO_2$ and $\Delta \mathring{V}O_2$, is also calculated. It is an indicator of metabolic fuel, approximately indicating which substrates are being oxidized (a ratio of 0.7, 0.8 and 1 is indicative of respectively mixed fat, proteins and carbohydrates use). RQ is also used as an indicator of the measurement quality, signaling technical problems such as air leaks.

Compared to other methods of EE measurement, IC is non-invasive and can be performed in various clinical situations. For example, this technique is now recommended to determine energy needs in critically ill patients (2-4) or considered in the management of critically ill survivors (5). The EE measurement using IC has been made easier since the development of a new-generation indirect calorimeter, promoted by the International Multicentric Study Group for Indirect Calorimetry (ICALIC) (6). This innovative device (Q-NRG, Cosmed, Rome, Italy) is simple to use: compact, battery- powered, warm-up free operation, and intuitive. It is the only device that has been validated against mass spectrometry, the gold standard technology for gas composition measurements (7). Advantageously for the post-ICU condition, the measurement can be performed in spontaneously breathing patients, using a canopy hood. The Q-NRG has been shown to be very precise and accurate in canopy mode compared to mass spectrometry measurement (7).

Several other indirect calorimeters are commercially available nowadays. The Quark RMR (Cosmed, Rome, Italy) can also be used in canopy mode. Recently, the Q-NRG has been compared to Quark RMR and offered same precision of EE measurement (8). However, among all devices, the Deltatrac metabolic monitor (Datex, Helsinki, Finland) has always been considered as the reference indirect calorimeter (1, 9). Its production has now ceased after the commercialization of more user-friendly devices and few centers still benefit from a support service for maintenance.

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If Q-NRG has been largely validated during mechanical ventilation, its validation in canopy mode is less extensive, especially against the Deltatrac II. The aim of the present study was to test the agreement of this new device with the still considered gold standard device in daily practice (Deltatrac II).

Methods

This observational study was conducted in an academic hospital after approval by the local IRB (National Ref B7072021000024, Local Ref 2021/122, 4th May 2021). Informed consent was obtained from the subjects prior to enrollment. The study was registered on clinicaltrials.gov, NCT05008757.

Population

Healthy adults were recruited among the students of the Sport Sciences and Physiotherapy Department of the Faculty of Medicine of our university and among athletes subscribing to the university's sports center. Exclusion criteria were inability to communicate in regional language (French), pregnancy and refusal to participate. Their demographic data (age, sex, measured weight, height, body mass index (BMI)) were recorded.

Indirect calorimeters

Both calorimeters were used according to the user manual instruction, after a dedicated supplemental maintenance session performed by certified technicians, according to manufacturers' recommendations.

The Q-NRG indirect calorimeter was used in canopy mode (7). A digital turbine flowmeter operates in series with the internal blower to draw air at constant flow rate through the canopy hood. The pumping rate is automatically calculated based on the patient's weight and can be adjusted during the measurement to prevent too high or too low CO_2 concentration into the hood. The measurement technology is based on in-line flow meters and high precision gas analysis, using the dynamic micro-mixing chamber technique with chemical fuel cell O_2 and non-dispersive infrared absorption digital CO_2 sensors. Mean values of $\Delta \mathring{V}O_2$ and $\Delta \mathring{V}CO_2$ are reported every 30 seconds. Gas analyzers are automatically calibrated against room air before each measurement. A calibration of the internal turbine flowmeter using a calibration syringe and a calibration of the gas analyzers against precision gas mixture were performed monthly, as recommended by the manufacturer.

The Deltatrac II was also used in canopy mode (10). This calorimeter is also based on the mixing-chamber technique. It consists of a differential paramagnetic oxygen analyzer (OM-101) with automatically compensated baseline drift, an infrared CO_2 sensor, and a constant flow generator. Mean values of $\Delta \mathring{V}O_2$ and $\Delta \mathring{V}CO_2$ are reported every minute. The device was still used in clinical practice in our hospital, thanks to the careful maintenance by an experienced technician from Acertys. The last maintenance was performed in 2020, including an ethanol burning test to calibrate the metabolic carts. Gas analyzers were manually calibrated before each measure with a pre-specified O_2 and CO_2 concentrations reference gas cylinder.

Indirect calorimetry

The participants were all tested in the same room, during similar time slot of the day (between 8 AM and noon), and under standardized conditions. IC was performed after a fasting period of at least 12 hours, and after abstention of moderate or vigorous physical activity for at least 12 hours. Participants were in supine position, in a quiet environment and without any sources of distraction. Before the initial indirect calorimetry assessment, they were motionless for at least twenty minutes while lying supine on a reclining bed, covered by a bed sheet. During the assessment, they were asked to stay awake and silent.

The two EE measurements with the two different devices were performed sequentially in a random order. Each measurement lasted at least 30 minutes, with the first 10 minutes used to establish stable baseline.

Statistical analysis

Prior to the study, the sample size calculation was performed using MedCalc software. According to previously published data, a mean difference of 45kcal/day was observed when comparing Q-NRG and other IC devices in different countries (6). It was estimated that 60 participants would be needed to observe a difference of 45 kcal/day between the two devices, with a limit of agreement of 52 kcal, considering a power $\beta = 90\%$ and a significance level $\alpha = 0.05$.

Statistical analysis was performed using R software (version 4.0.2 for Windows). Normality was assessed using the Shapiro-Wilk test. The results were expressed as means ± standard deviation (SD) for quantitative parameters, or as counts and proportions for qualitative parameters. Comparisons between data were made using paired t-test. Correlations between data were tested using Pearson test. The Q-NRG results were tested against the reference method (Deltatrac II) for bias using Bland-Altman analysis. A p-value < 0.05 was considered statistically significant.

Results

In total, 61 participants (52 men, 85.2%) were included. Their age was 25.7 ± 8.4 years. Their measured body weight was 72.7 ± 11.5 kg and their body mass index (BMI) was 23.3 ± 2.9 kg/m^2.

Table 1. — **Measured data using the two indirect calorimeters**

	Q-NRG®	Deltatrac II®	p-value
Energy Expenditure (kcal/day)	1816 ± 361	1809 ± 260	0.803
$\Delta\dot{V}CO_2$ (ml/min)	213 ± 40	219 ± 33	0.189
$\Delta\dot{V}O_2$ (ml/min)	263 ± 54	265 ± 38	0.582
RQ	0.82 ± 0.07	0.82 ± 0.07	0.483

RQ: respiratory quotient; $\Delta\dot{V}CO_2$: carbon dioxide production rate; $\Delta\dot{V}O_2$: oxygen consumption rate.

The recorded data are detailed in Table I. The EE, $\Delta\dot{V}O_2$, $\Delta\dot{V}CO_2$ and RQ were similar, whether they were measured using Q-NRG or Deltatrac II. There was a positive significant correlation between the two measured EE (Figure 1), with Pearson coefficient ρ =0.78 (p= <0.01).

Performances of the Q-NRG are represented in Bland–Altman plots (Figure 2). The Q-NRG slightly overestimated the EE compared to the Deltatrac II measure: bias ± limits of agreement was 7 ± 227 kcal/day. The systematic bias was -5.5 ± 32 ml/min and -2 ± 31 ml/min, respectively for $\Delta\dot{V}O_2$ and $\Delta\dot{V}CO_2$.

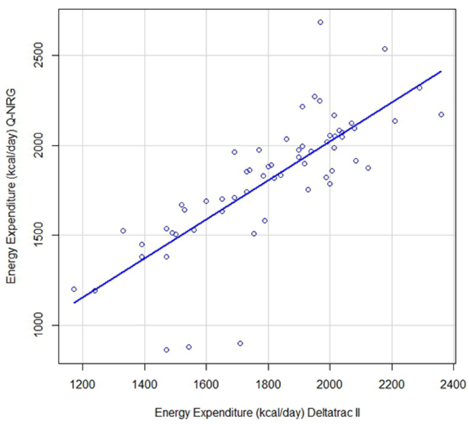
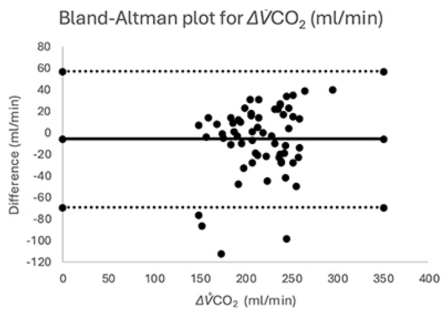


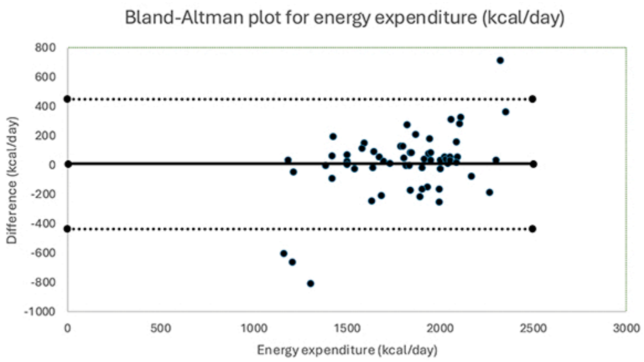
Figure 1. — Correlation between energy expenditure measured with the Q-NRG and the Deltratrac II devices.

Discussion

In the present cohort of young, healthy volunteers, the Q-NRG indirect calorimeter used in canopy mode performed similarly to the Deltatrac II device.

While its production has ceased, the Deltatrac II has long been considered as the gold standard calorimeter for use in clinical practice despite its known drawbacks: expensive and heavy-piece of equipment requiring careful calibration. The device has been validated in vitro as well as in clinical environment, such as in mechanically ventilated patients in whom it demonstrated high precision and accuracy (11). New modern devices breath-by-breath analysis of pulmonary gas exchange were then developed, and further tested against the Deltatrac II (12, 13). It was observed that these new devices (E-COVX, GE, Helsinki, Finland and Quark RMR, Cosmed, Rome, Italy) overestimate $\Delta\dot{V}O_2$ and $\Delta\dot{V}CO_2$ compared to Deltatrac II. On the contrary, in spontaneously breathing subjects, its performances were not better than those obtained with a handheld calorimeter (MedGem, Microlife, Golden CO, USA) (14).





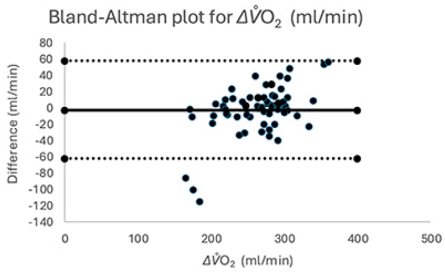


Figure 2. — Bland-Altman plots showing the difference in EE measurement (kcal/day), $\Delta\dot{V}CO_2$ measurement (ml/min) and $\Delta\dot{V}O_2$ measurement (ml/min) between Q-NRG and Deltatrac II devices in canopy mode. Mean differences are represented by dashed lines, limits of agreement are represented by dotted lines.

The Q-NRG device can be used in spontaneously breathing patients using a canopy hood or a face mask. A high accuracy was found in an in vivo study performed in 15 healthy volunteers, assessing agreement between the Q-NRG and a mass spectrometry gas analysis system. In the same population, a high intra- and inter-unit precision was also demonstrated (7). In another clinical study, the same team compared its performances to those of a commonly used device (Quark RMR) in 45 spontaneously breathing patients using a canopy hood. The EE was underestimated by the Q-NRG, with a bias of -14 ± 236 kcal/day (8). The Q-NRG has not been compared to other devices, except the Deltatrac II in the present study, in which a good reliability of the new device has been observed.

Mass spectrometry is recognized as the gold standard method for gas composition analysis. This strategy was used to validate the Deltatrac device that has thus been considered as the reference for indirect calorimetry (15). The only other indirect calorimeter that has been validated using this technique is the Q-NRG. From this point of view, and compelling results from all validation studies confirming the accuracy of this device, the Q-NRG could probably be considered as the new clinical reference method for energy expenditure measurement.

To maximize energy prescription in patients at risk of malnutrition, it is essential to have an accurate indirect calorimeter and to be able to easily measure energy expenditure in clinical daily practice. Its use is now encouraged, especially in elderly, obese or anorexic patients (16). Critical illness is probably the setting in which indirect calorimetry has been the most studied, due to the specific nutritional needs observed in these patients that cannot be estimated by predictive equations (17), the dangers of an under- or over- nutrition (18), and the fluctuations of their energy requirements throughout the illness trajectory (19). In particular, the ICU survivors are at risk of malnutrition (20), but their metabolic status and their energy expenditure are poorly investigated (21). In this context, guiding the nutritional delivery via indirect calorimetry and EE measurement would be judicious whenever possible, promoting an individualized approach (22).

The present study was conducted under controlled settings with two devices, whose maintenance and calibrations strictly followed the manufacturers' instructions. The sample size was adequate. The limitation of this study is related to the population, including young, healthy subjects. To perform an irrevocable validation of the Q-NRG against the standard reference used in clinical practice, hospitalized patients will have to be enrolled.

Conclusions

In young, healthy volunteers breathing spontaneously, the Q-NRG in canopy mode performed similarly to the Deltatrac II in terms of EE measurement. In addition to its previously demonstrated accuracy in mechanically ventilated patients, the current findings provide assurance for its application to spontaneously breathing subjects.

Declarations

Ethics approval and consent to participate: The present study was approved by the local Ethics Committee (National Ref B7072021000024, Local Ref 2021/122, 4th May 2021).

Consent for publication: Not applicable

Availability of data and material: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Competing interests: All authors declare that they have no competing interests in link with the present manuscript.

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Author's contribution: MF, JFK, AFR designed research; MF conducted research; MF, AFR analyzed data; MF and AFR wrote paper; JDF, JFK, BM, NP critically reviewed the manuscript. All authors approved the final version.

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