Short communication

Reproducibility of resting metabolic rate measurement in children

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The aim of the present study was to determine the reproducibility of measurement of resting metabolic rate (RMR) using a ventilated-hood indirect calorimeter in children using a short protocol suitable for the outpatient setting or home visit. The protocol consisted of an overnight (10–12 h) fast, 5–10 min supine rest, 5–10 min 'settling in' under the ventilated hood, and 12–16 min of measurement. Three measurements of RMR were made in eighteen healthy children (nine boys, nine girls, aged 6–11 years) on alternate days. Reproducibility of RMR was assessed using a reproducibility index and by calculating the CV for intra-individual measurements. The mean CV was 2·6 (SD 1·7)% and the reproducibility index was 95·0 %, indicating excellent reliability. The short protocol had higher reproducibility than more stringent protocols described in the literature. The new protocol has a number of practical advantages and should be adequate for most clinical or research purposes.

Children: Resting energy expenditure: Reproducibility

In children, most investigators measure resting energy expenditure under 'outpatient' conditions, i.e. resting metabolic rate (RMR) rather than BMR (Figeroa-Colon *et al.* 1996), but there is enormous variability between laboratories in measurement conditions. These differences are potentially important: duration of the pre-test fast; presence or absence of a fast (some investigators use postprandial measurements, e.g. Goran & Nagy, 1996); duration of the measurement period, since periods from as short as 5 min (Kien & Camitta, 1987; Frankenfield *et al.* 1996) to 60 min are used. The extent to which such differences in study protocols influence reproducibility of RMR measurement is an important but unresolved question. Reproducibility of the RMR measurement has implications for the number of RMR measurements required (Figeroa-Colon *et al.* 1996) and the ability to detect changes in RMR (Zemel *et al.* 1996). However, only one previous study has quantified reproducibility of RMR measurement in children. This study used a 15 min rest period and 30 min measurement period (Figeroa-Colon *et al.* 1996). In our previous studies (e.g. Reilly *et al.* 1996) we observed that shorter measurements (about 20 min) and pre-test resting periods (5–10 min after travel to the laboratory by car) encourage compliance, but the reproducibility of these measurements has not been formally assessed. The aim of the present study was to determine the reproducibility of RMR measurement using a short, simple protocol which is acceptable to children and suitable for the clinical setting.

Methods

Subjects

Subjects, nine boys and nine girls, were all healthy, not taking special diets or participating in extreme exercise, and not taking any medications. All were prepubertal (Tanner stage 1; Tanner, 1962) and Caucasian. Age range was 6·4–11·6 years. Children and their families gave informed consent for participation and the research was approved by the Yorkhill Hospitals Ethics Committee. Children were self-selected, and responded to a letter sent to a local school requesting study volunteers.

Measurement procedures

All children arrived for the measurement by car between 08.00 and 08.30 hours, after an overnight (10–12 h) fast. Children rested supine for 5–10 min, before measurement of RMR. The temperature of the room throughout was 22–23°. A 'Deltatrac' (Datex, Helsinki, Finland) ventilated-hood indirect calorimeter was used for measurement of RMR. *In vitro* testing has shown that Deltatrac measurement of gas

Abbreviation: RMR, resting metabolic rate.

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exchange is in good agreement with controlled gas infusion (infusion of CO_2 and N_2) which simulates RMR (Wells & Fuller, 1998). The Deltatrac was calibrated before each measurement, using reference gas, and periodically checked against alcohol burning and N_2–CO_2 infusion as previously described (Reilly *et al*. 1993). All measurements of RMR were made by the same trained observer who observed the measurement throughout. Three measurements of RMR were made in each child (on alternate days within the same week). During the measurement, children were instructed to lie quietly and motionless and to facilitate this they listened to music or story tapes.

After a 'settling in' period (range 5–10 min) a 'steady state' in RMR measurements had been achieved and the mean of a further 12–16 min was used as the RMR for each day. The 'steady state' was defined as the period of stable energy expenditure which followed the 'settling-in' period. This was ascertained by the investigator from the graphical output on the screen when a plateau was observed in successive minute-by-minute measurements. Each measurement was made 'blinded' to the results of previous measurements on each child. Measurements of height (to 1 mm) and weight (to 0·1 kg) were made using standard methods on each occasion and used to calculate BMI and BMI standard deviation scores relative to contemporary UK reference data (Cole *et al*. 1995).

Statistical analyses

Repeated measures ANOVA was used to test the significance of differences in RMR between days. Reproducibility of RMR was quantified in two ways: (1) CV; (2) calculation of a reproducibility index (variance in RMR between children/variance in RMR between children plus variance within children; Dunn, 1989). The sample size was deemed adequate to establish the CV and reproducibility index using previously published criteria (Figeroa-Colon *et al*. 1996).

Results

Patient characteristics

Physical characteristics of the subjects are summarized in Table 1.

Reproducibility of resting metabolic rate

There was no evidence of significant differences in RMR between days (ANOVA, $P = 0{\cdot}26$). The mean intra-individual CV was 2·6 (SD 1·7) %. The CV of RMR ranged from 0·1 to 7·2 % (Table 2), and was not altered by adjustment for fat-free mass or body mass. Mean measurement time (under the ventilated hood) was 15 (SD 1; range 12–17) min.

Table 1. Physical characteristics of subjects

	Mean	SD
Age (years)	9·0	1·5
Height (m)	1·35	0·12
Weight (kg)	33·1	9·0
BMI (kg/m^2)	17·8	2·8
BMI SDS	0·53	0·99

SDS, standard deviation score.

Table 2. CV of intra-individual resting metabolic rates (RMR) in eighteen children

	RMR (MJ/d)		
Child	Mean	SD	CV (%)
1	4·82	0·15	3·1
2	4·46	0·08	1·7
3	4·97	0·09	2·0
4	5·18	0·12	2·3
5	5·49	0·22	4·1
6	4·63	0·10	2·2
7	5·74	0·27	4·7
8	5·52	0·07	1·2
9	7·15	0·01	0·1
10	5·72	0·06	1·1
11	4·72	0·12	2·6
12	5·27	0·18	3·4
13	5·99	0·01	0·1
14	5·75	0·20	3·6
15	5·48	0·39	7·2
16	5·20	0·16	3·0
17	5·81	0·13	2·2
18	3·87	0·10	2·5
Mean	5·32	0·14	2·6
SD	0·72	0·09	1·7

Discussion

The present study showed that the protocol for measurement of RMR tested is highly reproducible. The only other directly comparable study, which involved longer pre-test and measurement periods, reported a higher intra-individual CV of measurement of 5·8 % in nineteen girls (Figeroa-Colon *et al*. 1996), and concluded that only one measurement of RMR was necessary. A study of reproducibility of postprandial measurement of RMR in children reported a mean CV of 5·4 % (Goran & Nagy, 1996). The degree of reproducibility in RMR required will depend on the circumstances. When testing for changes in RMR, for example, the size of the change and sample size will be crucial (e.g. Zemel *et al*. 1996). The results presented here should inform such considerations in future studies. However, it should be noted that reproducibility of RMR in children with disease might differ from that in healthy, self-selected children.

The use of less stringent test protocols in children is not only attractive from a practical point of view, particularly in clinical and outpatient settings, but might actually improve compliance with the protocol (Goran & Nagy, 1996), and hence measurement reliability. This might explain why the short, simple protocol used in the present study had higher reproducibility than longer, more stringent protocols. Earlier studies have shown improved compliance and data quality when children are allowed to watch television during the measurement (Klesges *et al*. 1993; Dietz *et al*. 1994; Goran & Nagy, 1996) and allowing the children to listen to music or story tapes during our protocol probably had a similar effect. The present study also supports the view that inpatient measurement conditions (i.e. BMR) are unnecessary for reliable measurement in children (Bandini *et al*. 1995; Figeroa-Colon *et al*. 1996) as in adults (Turley

et al 1993). The absence of a significant order effect on RMR in these subjects, who had not previously been exposed to or familiarized with measurements of this kind, is also encouraging. In individual children RMR measurement may be much less stable. In the present study subject 15 (Table 2) had a CV of 7 %, but there was no obvious reason for this: no evidence of non-compliance with measurement conditions; minute-by-minute variability in RMR within each measurement (an index of measurement quality) was low at <3 %.

We conclude that a protocol for outpatient measurement of RMR consisting of overnight fast, 5–10 min rest, 5–10 min 'settling in' and 12–16 min measurement in children is sufficiently reproducible for most practical purposes. This protocol has higher reproducibility than more classical alternatives.

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