Validation study of energy expenditure and intake during calorie restriction using doubly labeled water and changes in body composition¹–³

Lilian de Jonge, James P DeLany, Tuong Nguyen, Jennifer Howard, Evan C Hadley, Leanne M Redman, and Eric Ravussin

ABSTRACT
Background: Clinical trials involving calorie restriction (CR) require an assessment of adherence to a prescribed CR with the use of an objective measure of energy intake (EI).
Objective: The objective was to validate the use of energy expenditure (EE) measured by doubly labeled water (DLW), in conjunction with precise measures of body composition, to calculate an individual’s EI during 30% CR.
Design: Ten participants underwent 30% CR for 3 wk. During the last week (7 d), 24-h EE was measured in a respiratory chamber and simultaneously by DLW (EE_{DLW}). EI was calculated from 7-d EE measured by DLW and from changes in energy stores (ES) (weight and body composition). Calculated EI was then compared with the actual EI measured in the chamber by using the following equations: calculated EI (kcal/d) = EE_{DLW} + ΔES, where ΔES_{FM/FFM} (kcal/d) = (9.3 × ΔFM, g/d) + (1.1 × ΔFFM, g/d), FM is fat mass, and FFM is fat-free mass.
Results: We found close agreement (R = 0.88) between EE measured in the metabolic chamber and EE_{DLW} during CR. Using the measured respiratory quotient, we found that the mean (±SD) EE_{DLW} was 1934 ± 377 kcal/d and EE measured in the metabolic chamber was 1906 ± 327 kcal/d, ie, a 1.3 ± 8.9% overestimation. EI calculated from EE_{DLW} and from changes in ES was 8.7 ± 36.7% higher than the actual EI provided during the chamber stay (1596 ± 656 kcal/d).
Conclusions: DLW methods can accurately estimate 24-h EE during CR. Although the mean difference between actual and calculated EIs for the group was small, we conclude that the interindividual variability was too large to provide an assessment of CR adherence on an individual basis. Am J Clin Nutr 2007;85:73–9.

KEY WORDS Doubly labeled water method, DLW, energy intake, body composition, metabolic chamber

INTRODUCTION
Epidemiologic studies of diet and disease rely on an accurate determination of dietary intake. Although a wide range of carefully developed intake assessment tools are currently used, it is readily acknowledged that self-reported dietary intake via all methods is subject to large measurement errors; thus, more objective measures are necessary. Energy requirements in humans can be estimated with reasonable reliability and accuracy when body weight is stable (1–3); however, it is inherently more difficult to obtain accurate assessments during periods of positive or negative energy balance when body weight and, therefore, energy stores are fluctuating.

The First Law of Thermodynamics states that energy is conserved. In terms of human metabolism, energy intake (EI) is therefore equal to energy expenditure (EE) plus the changes in energy body stores. The use of doubly labeled water (DLW) for the assessment of total daily EE (TDEE) in free-living humans is well established and has been validated against several other methods, including metabolic chambers, with an accuracy of 1–2% and a precision of 5–7% (4–7). To assess EI from TDEE, one assumes that the individual is in energy and macronutrient balance. Little information exists on the use of TDEE during energy imbalance. For example, TDEE measured by DLW did not change in response to overfeeding in underweight adults, but no attempt was made to calculate EI (8). In another study, in which both TDEE (by DLW) and EI (by diet records) were measured simultaneously (9), most participants lost weight, but EI estimated from free-living EE and body weight changes was 221 ± 550 kcal/d larger than that calculated from food records, which lends support to the concept that food records underestimate true intake.

In the scope of the first long-term study of calorie restriction (CR) in nonobese humans with objective determinations of EE and intake—CALERIE (Comprehensive Assessment of Long-Term Effects of Reduction in Intake of Energy)—we conducted a 7-d room calorimeter study during 30% CR to validate 1) the use of DLW for the calculation of TDEE during a period of CR; 2) the ability of body weight, dual-energy X-ray absorptiometry (DXA), or both measurements at the beginning and end of a DLW study to estimate changes in body energy stores; and 3) the

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accuracy and precision of the determination of an individual’s EI calculated from DLW (TDEE) and DXA (energy stores) when compared with actual EI provided during a short period of CR.

SUBJECTS AND METHODS

Study participants

Participants were recruited according to the same inclusion and exclusion criteria used for enrollment in the Pennington Biomedical Research Center (PBRC) CALERIE study, ie, the subjects had to be 25–50 y (men) or 25–45 y (women) of age, have a body mass index (BMI; in kg/m²) of 25–30, be nonsmoking, and not be involved in >2 h/wk of aerobic exercise (10). Ten subjects (4 men and 6 women) were enrolled in the study. All participants completed a comprehensive medical history and physical examination and provided written informed consent. The Institutional Review Board of the PBRC approved both the study protocol and the consent form.

Study design

After screening, each participant was enrolled in the study for a total of 4 wk (Figure 1). During the first week, baseline testing was conducted (DXA and 24-h EE in the metabolic chamber) while the participants were provided a weight-maintaining diet. The participants then consumed a CR diet for 3 wk. During the first 2 wk the subjects were outpatients and during the last 7 d of the study the participants resided in the metabolic chamber. Body composition was measured in duplicate by DXA, both before and after the 7-d chamber stay, and body weight was measured daily after the subjects voided and before they consumed breakfast while the participants were wearing a hospital gown (metabolic weight). TDEE was measured simultaneously by respiratory gas exchange and DLW during this time period.

Diet

All meals were provided and prepared by the metabolic kitchen. At baseline, a weight maintaining, run-in diet (55% carbohydrate, 30% fat, and 15% protein) was provided for 7 d. Menu compositions were validated in our food laboratory. The participants consumed 4 meals each day; breakfast and dinner were consumed at the PBRC, and lunch and an evening snack were packaged for take-out. The participants were weighed daily, and caloric intake was adjusted when necessary to maintain weight stability. During the first 2 wk of CR, the EI provided was calculated as 70% of the EI required to maintain body weight as determined during baseline. The participants continued to eat breakfast and dinner at the Center, with lunch and an evening snack packed for take-out. The participants’ final week of CR was spent in the metabolic chamber. We selected this time period to capture a condition of active weight loss but at the same time to avoid the large shift in body water that usually occurs during initial periods of disturbed energy balance (CR or overfeeding). The dietary intake during the metabolic chamber was 70% of the EI provided during the metabolic chamber test at baseline and 58% of the EI in the run-in period. EI during the chamber test at baseline was 83 ± 6% of the EI in the run-in period.

Metabolic chamber

Twenty-four–hour EE (24-h EE) and substrate oxidation were measured in a metabolic chamber at baseline and between days 15 and 21 of the 30% CR. Each morning, the participants left the chamber at 0715 and reentered it before 0800 while the gas analyzers were calibrated. During this time the participants were allowed to shower but not to engage in any other activities. Meals were served according to a fixed schedule at 0815h, 1230, and 1800; a snack was provided at 2100. Microwave motion detectors provided continuous monitoring of the participants’

<table>
<thead>
<tr>
<th>Screening</th>
<th>Baseline</th>
<th>Calorie Restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>-7 -6 -5 -4 -3 -2 -1</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22</td>
</tr>
<tr>
<td>Anthropometrics</td>
<td>X</td>
<td></td>
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<tr>
<td>Health questionnaires</td>
<td>X</td>
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<tr>
<td>Weight</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Controlled feeding</td>
<td></td>
<td></td>
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<tr>
<td>Calorie restriction (30%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inpatient stay</td>
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<tr>
<td>Metabolic chamber</td>
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<tr>
<td>Urine collection</td>
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<tr>
<td>Doubly labeled water</td>
<td></td>
<td></td>
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<tr>
<td>Total body water</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| DXA | X | X

FIGURE 1. Experimental design. DXA, dual-energy X-ray absorptiometry.
spontaneous physical activity. During these 7 d, the participants were sedentary. The 2 metabolic chambers at the PBRC, each of which measures 10 feet (≈305 cm) × 14 feet (≈427 cm) × 8 feet (≈244 cm) and has a volume of ≈27 000 L, were designed to provide a pleasant ambiance for the study participants (11). At least once a month, the accuracy and precision of the calorimeters were assessed by 24-h propane combustion tests.

Doubly labeled water

The day before entering the chamber for 7 d (day 14), the participants were admitted to our inpatient unit and a fasting baseline urine sample was collected. Then, the participants drank from a stock solution of 2.2 g/kg total body water (TBW) of H218O (10%; Medical Isotope, Pelham, NH or Marshall Isotopes LTD, Be’er Tuvia, Israel) and 0.115 g/kg TBW of 2H2O (Isotec Inc, Miamisburg, OH or Cambridge Isotopes, Cambridge, MA), followed by 100–200 mL tap water used to rinse the dose container. After 2 voids, 2 consecutive timed urine samples were collected ≈4 and 6.5 h after dosing. While the participant was in the chamber, timed urine samples were collected each morning after breakfast (second daily void). The 2H and 18O isotope elimination rates (kH and kO) were calculated by using linear regression of the log of isotopic enrichments relative to predose enrichment using daily postdosing urine samples. TBW was determined from the enrichment at time zero, obtained from the regression line. The rate of carbon dioxide production was calculated by using the equations of Schoeller (12), which were later modified as follows (13):

\[ r_{CO_2} = \left( \frac{N}{2.078} \right) (1.007k_O - 1.041k_H) - 0.0246nH_2O_t \]

(1)

where N is TBW and H2Ot is the rate of fractionated evaporative water loss, which is estimated to be 1.05N (1.007k_O − 1.041k_H).

EE was calculated by multiplying rCO2 by the energy equivalent of carbon dioxide for an assumed respiratory quotient (RQ) of 0.882 (food quotient of the diet; FQ) at baseline and by using the 24-h RQ measured in the respiratory chamber during CR.

Body weight and composition

Body weight was measured on rising and after voiding while the subjects were wearing a gown. Gown weight was subtracted from total weight to obtain final body weight. Five DXA scans (QDR 4500A; Hologic, Waltham, MA) were performed throughout the study. One scan was conducted at baseline, and duplicate scans were made on day 14 (the afternoon before the 7-d chamber stay) and day 22 (immediately after the 7-d chamber stay) of CR. The scans were analyzed with the latest software (QDR for WINDOWS, version 11.1). The CVs for repeat measures (n = 38; JP Delany, unpublished observations, 2002) of the body-composition measurement lean mass, fat mass, and percentage body fat were 0.6%, 1.1%, and 1.1%, respectively. TBW in 8 of the 10 participants was remeasured at the end of the chamber stay (day 22) by deuterium dilution (14).

Calculations

The changes in body energy stores—fat mass (FFM) and fat-free mass (FFM)—were calculated from DXA-measured percentage body fat, from metabolic weight measured immediately before and after the 7-d stay in the metabolic chamber, and from the change in body weight calculated from a regression of measured daily weights throughout the 7 d. Estimates of EI were then calculated from TDEE measured by DLW and changes in body energy stores (ΔES). Calculated EI values were then compared with the actual EI (energy provided) during the chamber stay by using the following equations:

\[ EI \text{ (kcal/d)} = EE_{DLW} + \Delta ES \]

where ΔES was calculated by using the change in the average percentage body fat measured by DXA and the actual changes in body weight or the regressed weight change between days 14 and 22:

\[ \Delta ES_{weight} \text{ (kcal/d)} = 7.4 \times \Delta weight \text{ (g/d)} \]

(3)

\[ \Delta ES_{FM,FM} \text{ (kcal/d)} = (9.3 \times \Delta FM, \text{ g/d}) + (1.1 \times \Delta FFM, \text{ g/d}) \]

(5)

\[ \Delta ES_{FM,FM} \text{ (kcal/d)} = (9.3 \times \Delta FM, \text{ g/d}) + (1.1 \times \Delta FFM, \text{ g/d}) \]

(6)

Statistical analysis

Data in the text, tables, and figures are provided as means (±SDs) unless otherwise mentioned. Data analysis was performed by using SAS version 8.2 (SAS Institute, Cary, NC). Student’s t test for paired samples was used to determine differences between results, and linear regression models were used to calculate associations.

RESULTS

Study participants

Ten healthy persons (4 men and 6 women) were recruited for this study. Their baseline characteristics are presented in Table 1. The average weight loss during the 3 wk of CR was 2.3 ± 0.6 kg (range: 1.5–3.3 kg), of which only 22 ± 59% corresponded to a loss of fat mass. Changes in weight, FFM, and FM during the 7 d in the metabolic chamber are shown in Table 2. Consistent with the rather large decrease in FFM (>0.7 kg), TBW also decreased by (0.33 ± 1.76 kg) in the 8 subjects with available data at the end of the 7-d chamber measurement.

Calorie intake

Mean EI at baseline was 2465 ± 378 kcal/d. The average intake during the first 2 wk of CR (when the participants were outpatients) was 1665 ± 216 kcal/d, which represented a reduction in EI from baseline of 31.5 ± 3.5%. During the metabolic chamber measures, the average EI was 2037 ± 314 kcal/d at baseline and 1432 ± 224 kcal/d during the 7 d of CR in the chamber (days 15–21), which represented a 30% reduction in EI from baseline during the chamber stay. Thus, during the period...
when EI during CR was estimated in the chamber, the degree of
CR was 42% of baseline intake, compared with the baseline
intake before entering the chamber. Twenty-four–hour EE dur-
ing CR during the 7-d chamber study decreased from 2073
kcal/d at baseline to an average of 1906 ± 327 kcal/d, resulting
in an energy deficit of 24.9 ± 4.7% (Table 2).

Validation of TDEE by DLW during CR

Mean 7-d TDEE measured by DLW was 1874 ± 325 kcal/d
when the FQ (0.882) was used. When the average 24-h RQ
measured during the chamber stay (0.84 ± 0.03) was used, the
TDEE measured by DLW was 1934 ± 377 kcal/d (Table 2). In
comparison with 24-h EE measured in the metabolic chamber,
TDEE measured by DLW tended to be underestimated by 1.6 ±
7.7% (P = 0.08) and overestimated by 1.3 ± 8.9% (P = 0.08)
with the use of the FQ and measured RQ, respectively. Therefore,
for the remainder of this article, the calculations of TDEE mea-
sured by DLW are derived from measured RQ. We found a strong
correlation between TDEE measured by DLW and the average
7-d 24-h EE measured in the respiratory chamber (Figure 2A;
R² = 0.77, P < 0.05). The Bland-Altman plot (Figure 2B) showed no
significant systematic bias of one method over the other.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Sex</th>
<th>Race</th>
<th>Age</th>
<th>Height</th>
<th>Weight</th>
<th>BMI</th>
<th>Body fat</th>
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<td>1</td>
<td>M</td>
<td>W</td>
<td>34</td>
<td>1.81</td>
<td>87.1</td>
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<td>M</td>
<td>W</td>
<td>34</td>
<td>1.76</td>
<td>84.7</td>
<td>27.3</td>
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<tr>
<td>3</td>
<td>M</td>
<td>W</td>
<td>34</td>
<td>1.82</td>
<td>85.6</td>
<td>25.8</td>
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<td>4</td>
<td>F</td>
<td>W</td>
<td>28</td>
<td>1.70</td>
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<td>W</td>
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<td>36.1</td>
</tr>
<tr>
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<td>M</td>
<td>A</td>
<td>28</td>
<td>1.82</td>
<td>94.8</td>
<td>28.5</td>
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<tr>
<td>7</td>
<td>F</td>
<td>H</td>
<td>45</td>
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<td>1.68</td>
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<td>9</td>
<td>F</td>
<td>W</td>
<td>42</td>
<td>1.60</td>
<td>62.4</td>
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<td>36.8</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>A</td>
<td>32</td>
<td>1.60</td>
<td>70.3</td>
<td>27.5</td>
<td>32.4</td>
</tr>
</tbody>
</table>

x ± SD — — 36 ± 7 1.72 ± 0.08 79.9 ± 9.2 27.0 ± 1.4 30.5 ± 7.3

W, white; A, African American; H, Hispanic.

Estimates of changes in body energy stores

As shown in Table 2, the change in total energy stores (FFM + FM) calculated from changes in actual weight and from
changes in body composition measured by DXA was −337 ±
470 kcal/d. When using the change in weight calculated from 7-d
regression equations (intercept at times of beginning and end of
the chamber measurement) and DXA-measured percentage body
fat to calculate FFM and FM, the change in energy stores
was −304 ± 416 kcal/d.

Estimates of energy intake

When EI was calculated from actual changes in weight, FFM,
and FM, it was 1596 ± 656 kcal/d, ie, 8.7 ± 36.7% higher than
the actual EI. Similarly, when EI was calculated from changes
in FFM and FM and regressed weight it was 1626 ± 563 kcal/d, ie,
11.7 ± 30.2% higher than the actual EI. The relations between
calculated EI and EI provided in the chamber are shown in Figure
3, A and B. In each case, calculated EI was significantly corre-
lated with the actual EI that was provided (P < 0.05). When only
weight change was used to calculate EI (assuming a weight loss
of 7.4 kcal/g), EI was underestimated by 29.8 ± 60.5% and

| TABLE 2 |
| Calculations of energy intake (EI) on the basis of changes in energy stores by weight, regressed weight, fat mass, and fat-free mass¹ |

<table>
<thead>
<tr>
<th>Use of metabolic weight and DXA (day 14 and day 22)</th>
<th>Use of regressed daily weight (day 15 – day 22) and DXA</th>
</tr>
</thead>
<tbody>
<tr>
<td>24-h EE in chamber (kcal/d)</td>
<td>—</td>
</tr>
<tr>
<td>TDEE by DLW (kcal/d)</td>
<td>1934 ± 377 (1277–2474)</td>
</tr>
<tr>
<td>TDEE - 24-h EE (%)</td>
<td>1.3 ± 8.9 (–11.7–12.5)</td>
</tr>
<tr>
<td>∆Weight (kg)</td>
<td>−0.9 ± 0.8 (–1.6–0.3)</td>
</tr>
<tr>
<td>∆Fat mass (kg)</td>
<td>−0.2 ± 0.4 (–0.9–0.6)</td>
</tr>
<tr>
<td>∆Fat-free mass (kg)</td>
<td>−0.7 ± 0.9 (–1.9–0.8)</td>
</tr>
<tr>
<td>∆ES (kcal/d)</td>
<td>−337 ± 470 (–1085–454)</td>
</tr>
<tr>
<td>Provided EI (kcal/d)</td>
<td>1432 ± 224 (1116–1860)</td>
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<tr>
<td>Calculated EI by DXA and weight (kcal/d)</td>
<td>1596 ± 656 (337–2723)</td>
</tr>
<tr>
<td>—</td>
<td>1626 ± 563 (599–2552)</td>
</tr>
<tr>
<td>Difference between provided and calculated EI (%)²</td>
<td>8.7 ± 36.7 (–70–46)</td>
</tr>
<tr>
<td>—</td>
<td>11.7 ± 30.2 (–46–37)</td>
</tr>
</tbody>
</table>

¹ All values are x ± SD; range in parentheses. ES, energy stores; DXA, dual-energy X-ray absorptiometry.
² ES = fat mass + fat-free mass.
DISCUSSION

This study was the first to determine the ability of DLW to assess EE and EI during a period of CR. Our results indicate that free-living EE can be determined accurately and precisely by DLW during CR. However, our study also provides evidence that the combination of EE measured by DLW and changes in energy stores measured by DXA does not quantify EI with sufficient accuracy and precision over short periods of negative energy balance.

The DLW method has been very useful in the assessment of EI or energy requirements under conditions of weight stability or energy balance (1–3). This technique is quite robust but is subject to some potential sources of error, including the choice of RQ to calculate EE from carbon dioxide production. The RQ of the diet (FQ) is commonly used but assumes that the proportion of a macronutrient oxidized is equal to the proportion of the ingested...
macronutrient (9). This assumption is probably valid when individuals are in energy balance; however, during periods of negative energy balance, it is expected that the percentage of fat oxidized is higher than the actual percentage of fat in the diet. The results of our study validate the assessment of free-living EE during negative energy balance. Compared with indirect calorimetry assessed in the metabolic chamber, TDEE was 1.6 ± 7.7% lower when the FQ estimated from dietary intake was used. It is important to note, however, that despite the small difference between EE measured by the chamber and DLW, the precision (SD) was ≈10%, including errors from both methods. Importantly, we did not observe any associations between the degree of discrepancy in EE between the 2 methods and the accepted determinants of EE such as body weight or body composition. In contrast, Ravussin et al (4), who also used simultaneous measurements of EE over 7 d (in 12 males), previously reported that that DLW underestimated EE in heavier individuals with a higher fat mass, probably because of a larger sequestration of deuterium during fat synthesis. A possible reason for the different findings may be that BMI in our participants spanned only a narrow range (BMI: 24.4–28.5), whereas BMI in the earlier investigation spanned a much broader range (BMI: 19–56).

Our study was designed to determine the accuracy of assessing individual EI over a 7-d period and, therefore, to be used as an objective assessment of short-term compliance with CR. Energy stores before and after the 7-d chamber stay were determined by multiplying percentage body fat (DXA) by metabolic body weight to obtain FM and FFM. Changes in energy stores were then calculated by multiplying the changes in body weight by an energy content factor (7.4 kcal/g) or by adding the actual changes in energy in FM (9.3 kcal/g) and FFM (1.1 kcal/g). Because of normal daily fluctuations in body weight, we calculated the changes in energy stores from both changes measured in metabolic weight (from days 15 to 22) and in linear regression equations of daily weight changes over the 7-d period. When the change in body weight alone was used to estimate body energy stores, the difference between calculated and actual EI was −30% and −25% for the measured and regressed weight change, respectively. The assigned energy coefficient of 7.4 kcal/g body weight change assumes a weight loss of 75% FM and 25% FFM (17). However, we observed a mean weight loss composed of 22% FM and of 78% FFM. Consistently, the results improved at an overestimation of ≈10% when actual changes in FM and FFM were used. Although this value could be considered an acceptable result on average, the large variability noted between individuals was of concern. The range of comparison between the methods was −70% to 46% and −46% to 34% when actual weight change and regressed weight change, respectively, were used.

The observed and well-accepted accuracy and precision of DLW to measure 24-h EE suggest that a major source of the variance in the current estimates of individual EI during CR is caused by the random error of the measurement of body composition by DXA and the rather small changes in tissue mass during a short period of time (7 d in this study and a maximum of 14 d in most studies using DLW). At the outset, we questioned the use of the DXA measurements for small changes in body composition and therefore performed duplicate measurements before and after the 7-d chamber stay. In our hands the SD of FFM and FM by DXA is 320 g (CV: 0.6%) and 300 g (CV: 1.1%), respectively. A potential error of ±300 g for FM in 1 wk would result in an error of a ±2790-kcal change in fat energy stores or ≈40 kcal/d EI. For FFM, a measurement error of ±300 g would result in an error of ≈±50 kcal/d in calculated EI. On average, our participants lost 200 g FM and 700 g FFM over the week of CR, and the mean absolute change in FM and FFM was 380 and 960 g, respectively. This small change in FM (the major contributor to changes in energy stores) that approaches the resolution of the DXA method cannot accurately reflect changes in energy stores and can therefore cause large errors in the estimates of individual daily EI. It is also worth noting that the magnitude of the effect of a given DXA measurement error on estimates of daily EI is inversely related to the duration of the measurement interval. A simulation model of EI and body weight indicated that over an extended period of time, when changes in body weight and body composition are larger, the combination of DLW and body composition can accurately assess EI (17). However, when Westerterp’s model was applied to our study we found a mean difference between provided and calculated EI of 1.2% but a large precision (±11.9%). Unfortunately, it is problematic (cost and participant’s burden) to measure EE over periods longer than 2 wk to improve the precision of the method.

A shift in TBW is another potential factor that can influence assessments of body composition by DXA. Water shifts affect not only the accuracy of body-composition measures, but also the accuracy of DLW to assess TDEE. In an attempt to minimize this effect, our chamber study was performed during the third week of CR. The participants’ high ratio of FFM to FM loss in the chamber raised the possibility that participants might have become dehydrated and lost a higher ratio of water to FFM components than the ratio of 0.73 assumed in our energy coefficient of 1.1 kcal/g FFM. This could have caused our calculations to overestimate changes in body energy stores resulting from changes in FFM and thus affect our EI estimate. However, in the 8 participants for whom data on changes in FFM and TBW were available, the average ratio of ΔTBW to ΔFFM was 0.57. This suggests that the high ratio of ΔFFM to ΔFM in the chamber was not due to disproportionate water loss. To further test the possibility that errors in the assumed FFM energy content contributed to the degree of discrepancy between estimated and actual individual EI, we used 2 different approaches: 1) we calculated EI using coefficients both > and <1.1 kcal/g FFM, and 2) we also estimated changes in individual FFM energy stores by using the actual changes in TBW. None of these approaches substantially reduced the CV for individuals’ estimated versus actual EI. Thus, these findings do not support the concept that the magnitude of discrepancies between individuals’ estimated and provided EI can be attributed to errors in the estimated energy content of ΔFFM.

The results of this study, therefore, suggest that EI can be estimated accurately by DLW methods under conditions of negative energy balance. However, because an individual’s short-term change in energy stores cannot be assessed accurately and precisely by DXA, it implies, for the short-term, that EI cannot be assessed accurately during CR by a combination of DLW and DXA. This method, therefore, could be useful for estimating EI across a longer term, that is, several months when the potential sources of error in body-composition assessment would be much smaller relative to the actual changes. The average EI over a longer interval could, therefore, be estimated from the changes in
energy stores in conjunction with estimated average EE, based on ≥2 measures over the interval.

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