The contradiction of stable body mass despite low reported dietary energy intake in chronic haemodialysis patients

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Abstract

Background. Dietary energy intake (DEI) is reported to be below recommended values in a large proportion of stable chronic haemodialysis patients, while energy requirement appears not to be very different from that in healthy subjects. Nevertheless, body mass has often been reported to be stable over time. We hypothesized that underestimation of habitual DEI by self-reporting of food intake could explain the contradiction of a neutral energy balance despite an apparently insufficient DEI.

Methods. In a group of 38 adequately dialysed haemodialysis patients the values of self-reported DEI and body mass assessed by anthropometry were analysed over a 40-week study period. In the total group, body mass increased over time at a DEI of $29 \pm 5$ kcal/kg of desirable body weight per day. Self-reported DEI was factored by an estimate of the patient’s basal metabolic rate (BMR) to arrive at a DEI/BMR ratio. A total energy expenditure (TEE) of at least 1.27 times the BMR is presumed to be required to maintain body weight over time. A DEI that is lower than this minimum value of TEE in patients with stable body mass over time strongly suggests underreporting of habitual DEI.

Results. In 61% of the patients the DEI/BMR ratio was below 1.27. In these patients, body weight increased significantly over time, despite a DEI/BMR ratio of only $1.06 \pm 0.15$. Body mass index correlated inversely with total DEI ($r = -0.39$, $P < 0.05$) and the DEI/BMR ratio ($r = -0.60$, $P < 0.001$), indicating that self-reported DEI was lowest in overweight patients.

Conclusions. These observations suggest that the contradiction of a stable body mass over time despite an apparently insufficient DEI in haemodialysis patients is mainly explained by an underestimation of habitual DEI from self-reported food intake.

Keywords: anthropometry; dialysis adequacy; diet records; dietary energy intake; haemodialysis; nutritional status

Introduction

Energy requirements in haemodialysis patients appear to be not very different from that in healthy subjects, as resting energy expenditure and the energy required for physical activity are not different from that in healthy controls [1]. A dietary energy intake (DEI) of 30–35 kcal/kg/day is generally recommended in dialysis patients [2]. Reported habitual DEI in haemodialysis patients, however, is often below recommended values [3]. Most investigators presume that the low reported DEI is the main cause of frequently observed energy malnutrition in haemodialysis patients [3]. Short-term metabolic studies in stable haemodialysis patients suggest that the energy balance is negative if DEI falls below 35 kcal/kg/day [4]. In contrast, long-term studies in out-patient haemodialysis patients have shown that indices of body mass are stable over time, despite a reported DEI well below 30 kcal/kg/day [5,6]. Thus far, no convincing explanation has been given for the contradiction of neutral energy balance at an apparently insufficient DEI.

The habitual DEI in free-living dialysis patients can only be assessed using indirect, patient-dependent methods, including self-recorded food intake [2,7]. In healthy persons self-reported DEI has been validated against measurements of total energy expenditure (TEE) [8,9]. Accuracy varied considerably and under-reporting of DEI occurred frequently. Data on TEE in free-living dialysis patients are lacking. The TEE of a subject can be determined indirectly by multiplying an estimate of the basal metabolic rate (BMR) by the level of physical activity [10]. The BMR is mainly determined by body size, sex, and age, and can be
estimated accurately from anthropometric equations [11]. The minimal daily energy requirement in order to maintain body weight in totally inactive people is estimated to be 1.27 times the BMR [11]. This value is based on an 8-h period of bedrest and minimal physical during waking hours. A DEI that is lower than this minimum TEE value in patients with stable body mass over time strongly suggests underreporting of DEI [10].

The question we asked ourselves in this study is whether underestimation of habitual DEI by self-report could explain the contradiction of stable body mass despite an apparently insufficient self-reported DEI in stable haemodialysis patients.

Subjects and methods

Patients that participated in a Dutch prospective study on haemodialysis adequacy and nutrition with a complete follow-up of 40 weeks were included in this analysis.

The patients were adequately dialysed with a target dialysis dose, expressed as equilibrated Kt/V of at least 1.0. All patients were treated by haemodialysis three times weekly for at least 3 months using bicarbonate-based dialysate on low-flux dialyzers with low complement activation. They had to be in a stable clinical condition without hospitalization in the 3 months prior to the start of the study. All included patients gave informed consent and the study was approved by the Medical Ethical Committee.

Prescribed DEI was based on desirable body weight (DBW) described in the Metropolitan Life Insurance tables, adjusted for sex, frame size, and height [12]. A minimum energy intake of $1.27 \times BMR$ was prescribed in order to maintain DBW [11]. Prescribed protein intake during the study period was at least 0.9 g/kg DBW/day. The dieticians encouraged the patients to comply with the prescribed diet on a regular basis and modified the prescription if necessary.

Urea kinetic modelling was performed every 5 weeks in order to assess the delivered equilibrated dose of dialysis, expressed as $Kt/V_{eq}$, and the protein equivalent of total nitrogen appearance (PNA), which is an indirect estimate of dietary protein intake in stable patients. The applied urea kinetic methods are described in detail elsewhere [13].

DEI measurements

Habitual DEI was assessed from self-recorded food intake every 10 weeks. The patients were carefully instructed by a trained dietician to record their total oral food intake in a dietary diary during 7 consecutive days using household measures. The patients were instructed to measure utensils used daily before they started recording. The dietician contacted the patient if the food records were not completely clear. The recorded intake was analysed by a trained dietician using a nutritional database (BECEL-EXTRA, version 5, 1995, Vlaardingen, The Netherlands). Values of DEI were factored by DBW, actual body weight (ABW), and BMR based on ABW ($BMR_{ABW}$), estimated from the Schofield equations [11]. These equations are based on the largest and most comprehensive analysis of BMR to date.

Anthropometric measurements

Anthropometric measurements were performed at baseline and at 40 weeks. All anthropometric measurements were performed after the dialysis session by a single observer (W.D.K.). Skinfold thickness was measured using a Harpenden skinfold caliper (British Indicators Ltd, West Sussex, UK) at four sites. Biceps and triceps skinfold thickness was measured on the opposite arm of the arteriovenous fistula. Subscapular and suprailliac skinfold thickness was measured on both sides and the values were averaged. Skinfolds were measured thrice to the nearest 0.50 mm and the averaged value was recorded.

Percentage of DBW (%DBW) was calculated by dividing ABW by the patient’s DBW. Relative body weight (RBW) was calculated by dividing ABW by the patient’s normal body weight described in the National Health and Nutrition Examination Surveys (NHANES) I and II [14]. Total fat mass (TFM) and lean body mass (LBM) were calculated according to Durnin and Womersley [15] using ABW and skinfold thickness measurements. Relative total fat mass (RTFM) and relative lean body mass (RLBM) were calculated using normal fat mass and normal LBM values, which were calculated from the median body weight and median triceps skinfold thickness described in the NHANES reference tables [14]. RBW, RTFM, and RLBM are expressed as percentages of normal values. Body mass index (BMI) was used as a measure of obesity.

Statistical analysis

Data are presented as mean ± standard deviation. The mean of the eight urea kinetic measurements and the four dietary measurements available in each patient was used in the analysis.

Within-patient comparisons were performed using Wilcoxon signed rank tests and between-patient comparisons using Mann–Whitney U tests. Correlation was tested with Spearman’s correlation analysis. A two-sided P-value < 0.05 was considered statistically significant. All statistical calculations were performed using the SPSS for Windows statistical software package, release 10.0 (SPSS Inc., Chicago, IL).

Results

Thirty-eight out of the 58 patients who participated in the study on haemodialysis adequacy and nutrition had a complete follow-up of 40 weeks and were included in the analysis. Patient characteristics, the delivered dose of dialysis, and dietary intake variables during the study period are presented in Table 1. Eleven patients (29%) dialysed at home.

In the total group, ABW ($P < 0.05$) and TFM ($P < 0.001$) were lower than normal values described in the NHANES references tables. Self-reported DEI was significantly less than recommended energy requirements, and varied considerably between the individual patients (Figure 1). Reported DEI$_{ABW}$ was $< 30$ kcal/kg/day in 58% of the patients. In the total study group, ABW increased over time ($P < 0.05$), whereas LBM ($P = 0.097$) and TFM ($P = 0.19$) also showed a tendency to increase.
Table 1. Patient characteristics, body mass indices at baseline, and averaged delivered dialysis dose and dietary intake during the study period (n = 38).

<table>
<thead>
<tr>
<th>Male/female</th>
<th>Age (years)</th>
<th>Time on dialysis (months)</th>
<th>Kt/Vu</th>
<th>PNA (g/day)</th>
<th>BMI (kg/m²)</th>
<th>%DBW</th>
<th>RBW (%)</th>
<th>RTFM (%)</th>
<th>RLBM (%)</th>
<th>Plasma albumin (g/l)</th>
<th>DEI (kcal)</th>
<th>DEIABW (kcal/kg/day)</th>
<th>DEIDBW (kcal/kg/day)</th>
<th>DEIBMRABW</th>
<th>DEIBMRABW ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/female</td>
<td>26/12</td>
<td>55 ± 15</td>
<td>52 ± 58</td>
<td>1.13 ± 0.17</td>
<td>64 ± 12</td>
<td>23.7 ± 4.1</td>
<td>96 ± 15</td>
<td>83 ± 27</td>
<td>101 ± 13</td>
<td>42 ± 3</td>
<td>1949 ± 412</td>
<td>28 ± 7</td>
<td>29 ± 5</td>
<td>1.21 ± 0.23</td>
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</tbody>
</table>

Mean ± SD.

On the basis of the DEI/BMRABW ratio, patients were divided into groups with a DEI/BMRABW ratio of $\geq 1.27$ and $< 1.27$. Values of DEI and body mass variables at baseline and 40 weeks in the separate groups are presented in Table 2. Total DEI intake as well as DEI_{DBW} were lowest in the patient group with a DEI/BMRABW ratio of $< 1.27$. Remarkably, all variables of body mass were highest in this group, and ABW and LBM did not differ from normal values. The body mass variables tended to increase in both groups. A significant increase in body weight only occurred in the group with a DEI/BMRABW ratio of $< 1.27$, suggesting a positive energy balance, despite a clearly insufficient reported DEI.

In the total study group, RBW and RTFM at 40 weeks follow-up correlated inversely with absolute DEI ($r = -0.37$, $P < 0.05$ and $r = -0.33$, $P < 0.05$) and with the DEI/BMRABW ratio ($r = -0.49$, $P < 0.01$ and $r = -0.38$, $P < 0.05$). BMI also correlated inversely with DEI ($r = -0.39$, $P < 0.05$) and the DEI/BMRABW ratio ($r = -0.60$, $P < 0.001$) (Figure 2). In the eight patients with a BMI $> 25$ the DEI/BMRABW ratio was only 0.94 ± 0.14, while body mass variables in these patients remained stable over time.

Values of DEI and DEI_{DBW} were higher in the home dialysis patients (2201 ± 370 kcal/day, 32 ± 6 kcal/kg/day) than in patients that were dialysed at the dialysis centre (1850 ± 389 kcal/day, 28 ± 5 kcal/kg/day) ($P < 0.05$). In addition, the DEI/BMRABW ratio in home dialysis patients (1.32 ± 0.24) tended to be higher than that in the centre dialysis patients (1.17 ± 0.22) ($P = 0.116$). Seven out of the 15 patients (47%) with a DEI/BMRABW ratio $\geq 1.27$ were home dialysis patients vs four out of the 23 patients (17%) with a DEI/BMRABW ratio $< 1.27$.

**Discussion**

In this group of stable, adequately dialysed haemodialysis patients, long-term energy balance tended to be positive at a self-reported DEI that was on average significantly below recommended values. DEI varied considerably between patients and a large proportion of patients appeared to have a DEI significantly below the presumed level to maintain a neutral energy balance. Remarkably, body weight in these patient was not different from normal values, and ABW and LBM did not differ from normal values. The body mass variables tended to increase in both groups. A significant increase in body weight only occurred in the group with a DEI/BMRABW ratio of $< 1.27$, suggesting a positive energy balance, despite a clearly insufficient reported DEI.

A stable body mass over time despite a low DEI has also been reported in other long-term studies in haemodialysis patients. In the National Cooperative Dialysis Study self-reported DEI_{ABW} using food diaries was on average 24 kcal/kg/day and the DEI/BMRABW ratio was $\sim 1.05$. Body weight and body composition were stable over time [5]. In a study by Thunberg et al. [6], body weight and skinfold thickness were stable during an 18-month period, while self-reported DEI_{DBW} was $< 30$ kcal/kg/day in a large proportion of non-diabetic chronic haemodialysis patients. They did not find a relationship between the nutritional status and DEI. In contrast,
Low dietary energy intake in haemodialysis patients

Table 2. DEI and indices of body mass over time.

<table>
<thead>
<tr>
<th></th>
<th>DEI(<em>{\text{BMR}</em>{\text{ABW}}} \geq 1.27) ((n = 15))</th>
<th>DEI(<em>{\text{BMR}</em>{\text{ABW}}} &lt; 1.27) ((n = 23))</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEI (kcal/day)</td>
<td>2263 ± 366</td>
<td>1745 ± 299</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DEI(_{\text{DBW}}) (kcal/kg/day)</td>
<td>34 ± 4</td>
<td>26 ± 34</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DEI/(\text{BMR}_{\text{ABW}})</td>
<td>1.44 ± 0.12</td>
<td>1.06 ± 0.15</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI (kg/m(^2))</td>
<td>Baseline 21.9 ± 1.7</td>
<td>40 weeks 22.1 ± 1.6</td>
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</tr>
<tr>
<td></td>
<td>0.156</td>
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<td></td>
<td>24.9 ± 4.8</td>
<td>25.2 ± 4.8</td>
<td>0.101 0.014</td>
</tr>
<tr>
<td>ABW (kg)</td>
<td>66.3 ± 8.2</td>
<td>40 weeks 66.9 ± 8.1</td>
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<tr>
<td></td>
<td>0.197</td>
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<tr>
<td></td>
<td>74.3 ± 9.6</td>
<td>75.3 ± 9.7</td>
<td>0.021 0.016</td>
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<tr>
<td>DBW (%)</td>
<td>100 ± 8</td>
<td>40 weeks 101 ± 7</td>
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<tr>
<td></td>
<td>0.221</td>
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<tr>
<td></td>
<td>111 ± 18</td>
<td>113 ± 18</td>
<td>0.025 0.024</td>
</tr>
<tr>
<td>RBW (%)</td>
<td>90 ± 8</td>
<td>40 weeks 91 ± 8</td>
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<tr>
<td></td>
<td>0.245</td>
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<tr>
<td></td>
<td>100 ± 18</td>
<td>101 ± 18</td>
<td>0.025 0.059</td>
</tr>
<tr>
<td>TFM (kg)</td>
<td>16.0 ± 4.8</td>
<td>40 weeks 16.4 ± 4.3</td>
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<tr>
<td></td>
<td>0.363</td>
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<tr>
<td></td>
<td>20.7 ± 6.8</td>
<td>21.2 ± 7.2</td>
<td>0.316 0.017</td>
</tr>
<tr>
<td>RTFM (%)</td>
<td>74 ± 20</td>
<td>40 weeks 77 ± 23</td>
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</tr>
<tr>
<td></td>
<td>0.394</td>
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<tr>
<td></td>
<td>88 ± 29</td>
<td>91 ± 31</td>
<td>0.287 0.137</td>
</tr>
<tr>
<td>LBM (kg)</td>
<td>49.6 ± 7.8</td>
<td>40 weeks 49.9 ± 7.8</td>
<td>-----</td>
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<tr>
<td></td>
<td>0.496</td>
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<td>-----</td>
</tr>
<tr>
<td></td>
<td>53.0 ± 7.8</td>
<td>53.3 ± 8.1</td>
<td>0.144 0.202</td>
</tr>
<tr>
<td>RLBM (%)</td>
<td>96 ± 8</td>
<td>40 weeks 96 ± 8</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td>0.609</td>
<td></td>
<td>-----</td>
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<tr>
<td></td>
<td>104 ± 15</td>
<td>104 ± 14</td>
<td>0.212 0.051</td>
</tr>
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Mean ± SD. *P value of anthropometric variables at baseline between patient groups.

In this study food was supplied by the investigators and consumed at the research centre. Assessment of DEI was not biased by self-reporting of the patients. The discrepancy between a clearly insufficient DEI and a neutral to even positive energy balance observed in our and other long-term studies strongly suggests underestimation of habitual energy intake in out-patient haemodialysis patients.

Underestimation of habitual energy intake from self-reported food intake is generally recognized in the healthy population. In free-living subjects, self-reported DEI has been validated against TEE measured by the doubly labelled water method [9]. With this method, carbon dioxide production can be determined from the difference in elimination rate of deuterium and \(^{18}\)O for a period of 1–3 weeks. TEE is then calculated from the carbon dioxide production and an estimate of the respiratory ratio. The doubly labelled water method is an accepted reference method for assessing TEE, because it is accurate and not biased by the subjects studied [8]. Underestimation of habitual DEI up to 50% has been reported in healthy persons [9]. The greatest underestimate of DEI was reported in the subjects with the lowest self-reported intake. A good agreement was found between self-reported habitual energy intake and TEE in the subjects with the highest energy intakes [16]. Particularly obese subjects significantly underestimate their DEI, probably due to underreporting [9]. Thus, the apparent underestimation of habitual DEI by haemodialysis patients and the inverse association between BMI and self-reported DEI found in our study are in line with observations in normal subjects.

An alternative explanation for the stability of body mass despite low reported DEI has been proposed by Uribarri et al. [17]. They suggest that the low daily energy requirement observed in their peritoneal dialysis patients is due to the relatively low LBM, which was determined by creatinine kinetics. Remarkably, averaged triceps skinfold thickness, mid-arm circumference and mid-arm muscle circumference values in their dialysis patients were quite similar to the median values of the NHANES reference population. This suggests that body composition of their patients was not very different from normal. Based on the data provided by Uribarri et al. [17], we have argued that a low level of physical activity could also explain the apparently low energy requirements in their dialysis patients [18]. A study by Arkouche et al. [19] in peritoneal dialysis patients provides additional arguments to question the usefulness of relating energy expenditure to LBM based on creatinine kinetics. In that study, the resting energy expenditure did not correlate with the LBM that was determined by creatinine kinetics.

The results of our study may be biased, because we did not actually measure BMR in our patients. BMR was estimated from anthropometric equations based on healthy people [11]. Dissimilarities in body composition between healthy subjects and chronic haemodialysis patients might affect the validity of BMR equations that are based on studies in the normal...
population. However, the haemodialysis patients included in our study were relatively well nourished and body composition, particularly LBM, did not differ significantly from that in the normal population. In this respect, therefore, there appears to be no reason to question the validity of the BMR equations in our patient group. As far as we know there are no published studies available that have compared measured BMR with BMR estimated from anthropometric equations in the dialysis population. Studies that have compared measured BMR between stable haemodialysis patients and healthy subjects did not reveal significant differences between the groups [1,4].

Although the Schofield equations are based on the largest and most comprehensive analysis of BMR to date, there is evidence that they may overestimate BMR in some populations [20]. Besides, BMR varies between individuals with similar body weight and body composition by ~8–12% [20]. It is likely that the variation in BMR is related to some extent to genetic polymorphisms of mitochondrial uncoupling proteins, which have thermogenic properties that suggest involvement in the control of metabolic efficiency. The del/del UCP2 genotype has been reported to be associated with a reduced resting energy expenditure in Pima Indians and an enhanced metabolic efficiency in peritoneal dialysis patients [21,22]. As we did not screen our patients for these uncoupling protein polymorphisms, the BMR equations could have led to an overestimation of actual BMR and under-estimation of the DEI/BMR ratio in some haemodialysis patients. On the other hand, these genetic polymorphisms account for only 5–11% of the variation in resting energy expenditure [21]. A reduction in the energy expenditure of the native kidneys of dialysis patients could also contribute to lower BMR values. However, the potential reduction in energy expenditure due to function loss of native kidneys appears to be clinically irrelevant, as resting energy expenditure in healthy subjects does not differ from that in nondialysed patients with advanced renal failure or maintenance haemodialysis patients [1,4]. Notably, the low DEI/BMR ratios in our patients were mainly due to low reported DEI (Table 2). We therefore believe that the apparently low DEI in our dialysis patients is mainly explained by underreporting.

Our study does not answer the question why self-recorded food intake appears to underestimate habitual DEI. In theory, systematic errors related to the assessment method and patient-related errors can be responsible for the underestimation [7]. Validity of DEI assessed from food records using estimated weights of food is dependent on the quality of the applied food tables, correct coding of the food items, and adequate instruction of the patients. We think that systemic errors related to the applied food table and coding are small. A recent Dutch nutritional database was used in the calculations and the dieticians contacted the patients if the food records were not clear. In addition, all patients received personal instructions by a dietician. The use of household measures to estimate weights of ingested food might also introduce errors. However, studies that compared DEI assessed from estimate-weight food records with actual weighing of food showed no difference or a positive bias [7]. In a separate study in 10 haemodialysis patients, we compared the applied food diary based on household measures with weighing of food. The food diary overestimated DEI by 5.6 ± 9.5%. The difference was below 10% in eight of the 10 studied patients. Thus, a systematic methodological bias appears not to be responsible for the low reported DEI in our patients. We therefore think that under-reporting of food intake is the main source of low reported habitual energy intake, possibly by underreporting energy-rich snack food.

The low reported DEI in dialysis patients could also be related to a reduced level of physical activity. Recently, Johansen et al. [23] reported that habitual physical activity in haemodialysis patients, assessed using a questionnaire and accelerometry, was significantly lower than that in healthy sedentary subjects. Estimated TEE in the dialysis patients was lower as well. The home dialysis patients in our study had higher values of DEI than centre dialysis patients. Although we did not assess physical activity, the level of physical activity in home dialysis patients is probably higher than that in centre dialysis patients. The higher value of the DEI/BMR ratio in home dialysis patients is in line with this presumption. Energy requirements to maintain energy balance in dialysis patients may be lower than currently recommended, as these recommendations are based on the assumption that the physical activity level of dialysis patients is not different from that in healthy sedentary people [2].

The degree of underestimation of habitual DEI by self-recording in our patient group cannot be determined, because we did not measure TEE. To date there are no validated, unbiased methods to measure TEE in haemodialysis patients during daily life. TEE can be estimated from 24 h indirect calorimetry measurements performed in a respiration chamber, but as far as we know there is no published data available on this issue in dialysis patients. Besides, living in a respiration chamber during one day does not reflect daily life. The doubly labelled water method has never been used in this patient group. We performed a pilot study in two haemodialysis patients using only deuterium to study the effect of the dialysis procedure on the deuterium concentration. The deuterium concentration decreased by ~66% during dialysis, probably due to a large flux of water during the dialysis session. Besides, bicarbonate dialysis affects carbon dioxide generation, due to a bicarbonate flux from the dialysate to the patient [24]. These phenomena affect the validity of the doubly labelled water method in haemodialysis patients, so modifications will be needed.

In conclusion, our study suggests that the contradiction of a stable body mass over time despite an apparently insufficient DEI in haemodialysis patients
is mainly explained by an underestimation of habitual DEI from self-reported food intake. A low level of physical activity may also be partly responsible for the apparently reduced energy requirements in haemodialysis patients. Assessment of TEE using accurate, objective methods is urgently needed to determine optimal energy requirements in dialysis patients.

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