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*Original Article*

# Body composition in patients treated with peritoneal dialysis

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**Abstract**

**Background.** Malnutrition is a common complication in uremia and during maintenance dialysis. Several factors contribute to its development. Different modes of dialysis treatment may differ in their effects on nutritional status.

**Methods.** In order to analyse the nutritional consequences of peritoneal dialysis (PD), body composition analyses were performed in PD patients between February 1993 and March 1996. Body cell mass (BCM) was estimated from measurements of total body potassium (TBK) in a whole-body counter. Total body water (TBW) was determined by measurement of tritiated water. Body fat (BF) was calculated from body weight (BW), TBK and TBW. Observed values were related to predicted (o/p) derived from local population studies.

**Results.** Sixty patients were repeatedly investigated during the study period. Of these, 34 were investigated during the first year of PD. At the start of dialysis, TBK o/p was 0.94 and BF o/p 0.76. No change in body composition was seen during the observation period in the group as a whole. However, within the group individual changes in BW were strongly correlated with individual changes in BF ($r=0.66$, $P=0.0001$). Twenty-six patients were examined during the second and third year of PD. In this group, BW o/p remained constant over time. However, there was a small but significant decline of TBK o/p and a concomitant increase of BF o/p ($P<0.05$). No correlation was observed between changes in TBK and changes in serum albumin.

**Conclusions.** The results of this study indicate, that there may be a risk for further reduction of body cell mass during long-term PD treatment, while body energy stores are maintained or even increased.

**Key words:** body composition; malnutrition; peritoneal dialysis; total body potassium; total body water; body fat

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## Introduction

Malnutrition is a common complication in uremia and during maintenance dialysis [1–3] which is associated with increased morbidity and mortality [4–7]. Several factors contribute to the protein-energy malnutrition in dialysis patients and various dialysis modalities may differ in their effect on nutritional status [8].

Peritoneal dialysis (PD) may offer potential nutritional advantages compared with hemodialysis in that it provides a continuous energy supply, which may have a protein-sparing effect. In addition, the catabolic stimuli of hemodialysis, e.g. blood–membrane interactions, are avoided. Protein losses in the peritoneal dialysate appear to be of the same magnitude as in various hemodialysis modalities. However, increased abdominal filling and discomfort combined with suppressed appetite as a consequence of glucose uptake are factors that may negatively influence nutritional status in PD patients [9].

The risk of malnutrition in PD is supported by the cross-sectional study of Young *et al.* which showed that signs of malnutrition were present in a considerable proportion of patients who had been on PD for more than 3 months [2]. In this multi-center study, nutritional status was assessed by anthropometric and biochemical methods.

At the Department of Nephrology, Sahlgrenska University Hospital in Gothenburg, we used body composition analyses to evaluate the nutritional effects of low protein diet in predialytic patients [10] as well as to study the nutritional status of patients on maintenance hemodialysis [11]. In 1993, body composition analyses were included as a measure of nutritional status in the regular follow-up of PD patients. The aim of the present study was to evaluate changes in body composition during long-term PD treatment.

## Subjects and methods

From February 1993 to March 1996, 136 patients with end-stage renal disease (ESRD) were treated with PD at the Department of Nephrology, Sahlgrenska University Hospital. With the exception of 26 patients, who were on PD treatment for only a short time during the study period, or were not willing to participate, all patients were studied

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regularly using body composition analyses, as part of our routine follow-up program. The first investigation of body composition was planned for the start of dialysis, and then repeated every 6 months, close to the routine evaluation of dialysis efficacy.

Fifty patients had only one body composition determination carried out during this period. Hence, by the end of March 1996, 60 patients had been examined on two or more separate occasions. These 60 patients constitute the patient population of the study.

### *Patient population*

The patients were divided into two subgroups according to when the first body composition determination (i.e. the baseline determination) was performed in relation to the start of PD treatment. Patients who had their initial body composition determination performed within 3 months of the start of dialysis (Early group) were analysed separately from patients whose first determination of body composition was performed later during the treatment period (Late group).

*Early group*. Thirty-four patients had their baseline determination carried out within 3 months of initiating dialysis (median time on PD 0.5 months, mean time 0.8 months), with subsequent follow-up investigations carried out during a mean treatment time of 10.7 months on PD (median 9 months, range 5–32 months). On average, 3.0 determinations were performed with a mean time of 9.6 months (range 4–31.5 months) between the first and the last determination. Eighty-nine percent of all body composition determinations in this group were performed within the first 12 months on PD.

*Late group*. Twenty-six patients had their baseline body composition determination carried out after a mean PD treatment duration of 10.5 months (median 9 months, range 4–25.5 months). The majority of these patients were already on PD treatment, when body composition analyses were included in the follow-up program in 1993. They were then studied repeatedly with their last determination performed after 10–45 months (median 26 months) on PD. An average of 3.3 examinations were performed with a mean time between the first and last examination of 16.5 months (5–33 months). Two-thirds of the examinations in the Late group were carried out after more than 12 months on PD.

### *Patient characteristics*

The demographic data at the start of dialysis are presented in Table 1. The patient population is divided into the two study groups and the remaining group of patients without repeated body composition determinations. The two study groups did not differ from one another or from the patients who were not examined repeatedly with regard to the underlying renal diagnoses, sex distribution or body weight. The only observed difference was a slightly younger age in the Early group.

## *Methods*

Nutritional status was assessed by determination of body composition in both study groups. All measurements were obtained after the abdomen was drained of dialysis fluid.

*Body weight* (BW) was recorded on a digital scale to the nearest 0.1 kg with the patients dressed in light underwear.

*Body height* (BH) was measured on a wall-mounted stadiometer with the patients standing upright without shoes.

*Total body potassium* (TBK) was determined by counting the 1.46 MeV gamma radiation from the naturally present isotope $^{40}K$ (which is a constant fraction of all natural potassium) in a high-sensitivity $3\pi$ whole-body counter, as described previously [12]. The standard deviation (SD) of a single TBK determination was approximately 80 mmol [13].

*Total body water* (TBW) was determined by isotope dilution of tritiated water (THO) [13]. The patients were given 100 uCi (3.7 MBq) of THO orally, and TBW was determined from plasma samples taken before ingestion and after 3 h of equilibration. The activity of plasma water was counted in a liquid scintillation counter. The coefficient of variation of a single TBW determination was 3.2% [13].

*Total body fat* (BF) was calculated according to the 'four compartment model', as previously described by Bruce *et al.* [13]. In this model, BW is the sum of four compartments: fat-free extracellular solids (FFECS), body cell mass (BCM), extracellular water (ECW) and BF. The input variables are TBK, TBW, BW and normal body weight (BWnorm). The BWnorm for each patient was taken from Swedish and Norwegian population reference tables [14,15].

The observed values of TBK, TBW and BF were compared with the corresponding predicted values for age, sex, height and BWnorm based on local studies of 476 healthy normal subjects using this model [13].

The individual BW, TBK, TBW and BF values were then expressed as the ratio between the observed and predicted value (o/p). Thus, a value of 1.0 means that the actual observed value is equal to the predicted value, whereas a value below 1.0 indicates that the observed value is less than what should be expected in a healthy subject of the same sex, age and height and of normal body weight.

**Table 1.** Patient characteristics at start of peritoneal dialysis ($n = 136$)

| | *n* | Sex *n* (%) | | Diagnosis *n* (%) | | | BW mean (SE) | BWo/p mean (SE) | Age mean (range) |
|---|---|---|---|---|---|---|---|---|---|
| | | m | f | DM | PRD | other | | | |
| Patients with repeated examinations | | | | | | | | | |
| Early group | 34 | 22(65) | 12(35) | 9(26) | 22(65) | 3(9) | 70.4(2.5) | 0.955 ± 0.030 | 52*(32–83) |
| Late group | 26 | 15(58) | 11(42) | 6(23) | 16(62) | 4(15) | 65.1(2.3) | 0.933 ± 0.021 | 56(27–82) |
| Patients without repeated examinations | | | | | | | | | |
| | 76 | 52(68) | 24(32) | 16(21) | 53(70) | 7(9) | 67.6(1.4) | 0.933 ± 0.018 | 58(26–84) |

*$P < 0.05$ compared with patients without repeated examinations. DM = diabetic nephropathy, PRD = primary renal disease, other = nondiabetic systemic renal disease. BW = observed body weight at start of PD (kg). BW o/p = observed body weight at start of PD related to predicted body weight for age, sex and height (see text).

In the patients of the Early group, the BW at start of peritoneal dialysis (Table 1) was the BW measurement at the first body composition analysis. In other patients, the corresponding BW value was the BW recorded in the case record at 1 month after the start of PD.

*Serum albumin* was measured by nephelometry. The reference value of the local accredited laboratory was 37–48 g/l.

*Peritoneal clearance* was determined according to the Peritoneal Dialysis Capacity (PDC) model, as described previously [16]. In this model, 24 h urine and dialysis fluids are collected and analysed for urea and creatinine. In addition, the change of the body creatinine and urea pools are measured.

*Residual renal function* (RRF) was calculated as the mean of 24 h urea and creatinine clearances.

*Total creatinine clearance* was defined as the sum of the peritoneal clearance and RRF. In the majority of patients this was determined on the day before the measurement of body composition.

### *Statistical methods*

Standard statistics were used to describe the salient features of interest. Nonlinear changes over time, i.e. change per month, in the outcome variables (BW, TBK, TBW, BF and serum albumin) were analysed by analysis of covariance. Individual changes in outcome variables were inter-correlated using the Pearson correlation method of analysis. A *P*-value less than 0.05 was considered significant.

## Results

### *Early group*

At the start of dialysis, observed TBK and BF values were slightly lower than the predicted values ($P<0.05$). The observed values, and the ratios between the observed and predicted values, are presented in Table 2. None of the body composition variables changed significantly during the observation period. Also, the serum albumin concentration remained unchanged (Table 2).

Although there were no observed differences in the group as a whole, individual changes occurred as depicted in Figure 1. The individual changes in BW were strongly correlated ($r=0.66$) with individual changes in BF, but were not correlated with changes in TBK or TBW (Table 3).

The individual changes in serum albumin did not correlate with individual changes in TBK ($r=0.02$; n.s.).

The total weekly creatinine clearance was 70.6 l/1.73 $m^2$ body surface area (BSA) (42–105 l) at baseline and did not change significantly during the study period, being 72.5 l/1.73 $m^2$ BSA (50–112 l) at the final examination. RRF at baseline was 2.6 ml/min/1.73 $m^2$ BSA (0.1–6.0 ml/min) and 2.0 ml/min/1.73 $m^2$ BSA (0–6.9) at the end of follow-up.

Changes in RRF did not correlate with changes in BW, TBK, TBW, BF or serum albumin.

### *Late group*

The baseline values of BW and BF (4–25.5 months after the start of dialysis) did not differ from the predicted values and BW did not change during follow-up. However, the initial TBK was significantly lower than predicted ($P<0.05$) and decreased even further during the observation period ($P<0.05$). In contrast, a significant increase in the BF o/p was observed ($P<0.05$) (Table 2).

**Table 3.** Correlations between changes in BW to the other metabolic variables*

| | | Correlation coefficient | Significance |
|---|---|---|---|
| Early group | | | |
| Changes in | TBK | 0.28 | n.s. |
| | TBW | 0.12 | n.s. |
| | BF | 0.66 | $P=0.0001$ |
| Late group | | | |
| Changes in | TBK | 0.66 | $P=0.0002$ |
| | TBW | 0.20 | n.s. |
| | BF | 0.67 | $P=0.0004$ |

*Pearson correlation analysis.

**Table 2.** Metabolic variables at baseline and during follow-up

| | | Early group | | | Late group | | |
|---|---|---|---|---|---|---|---|
| | | Observed/predicted mean ± SE | Significant change over time*** | Actual data mean ± SE | Observed/predicted mean ± SE | Significant change over time*** | Actual data mean ± SE |
| BW o/p | first* | 0.95 ± 0.03 | | 70.4 ± 2.5 kg | 0.97 ± 0.03 | | 67.6 ± 2.5 kg |
| | last** | 0.97 ± 0.03 | n.s. | 71.3 ± 2.5 kg | 0.98 ± 0.03 | n.s. | 68.3 ± 2.5 kg |
| TBK o/p | first* | 0.94 ± 0.02 | | 3149 ± 126 mmol | 0.94 ± 0.03 | | 2945 ± 175 mmol |
| | last** | 0.94 ± 0.02 | n.s. | 3098 ± 115 mmol | 0.88 ± 0.03 | $P<0.05$ | 2742 ± 162 mmol |
| TBW o/p | first* | 1.03 ± 0.02 | | 41.3 ± 1.3 kg | 1.00 ± 0.02 | | 38.3 ± 1.8 kg |
| | last** | 1.02 ± 0.02 | n.s. | 41.1 ± 1.4 kg | 1.03 ± 0.03 | n.s. | 39.3 ± 1.6 kg |
| BF o/p | first* | 0.76 ± 0.09 | | 13.7 ± 1.6 kg | 0.87 ± 0.08 | | 15.5 ± 1.6 kg |
| | last** | 0.83 ± 0.10 | n.s. | 14.8 ± 1.7 kg | 0.92 ± 0.09 | $P<0.05$ | 16.1 ± 1.7 kg |
| Albumin/s | first* | 33.9 ± 0.7 g/l | | | 32.2 ± 1.0 g/l | | |
| | last** | 33.3 ± 0.8 g/l | n.s. | | 30.0 ± 0.9 g/l | n.s. | |

*First examination during observation time; **last examination during observation time; ***nonlinear change over time analysed by the analysis of covariance.

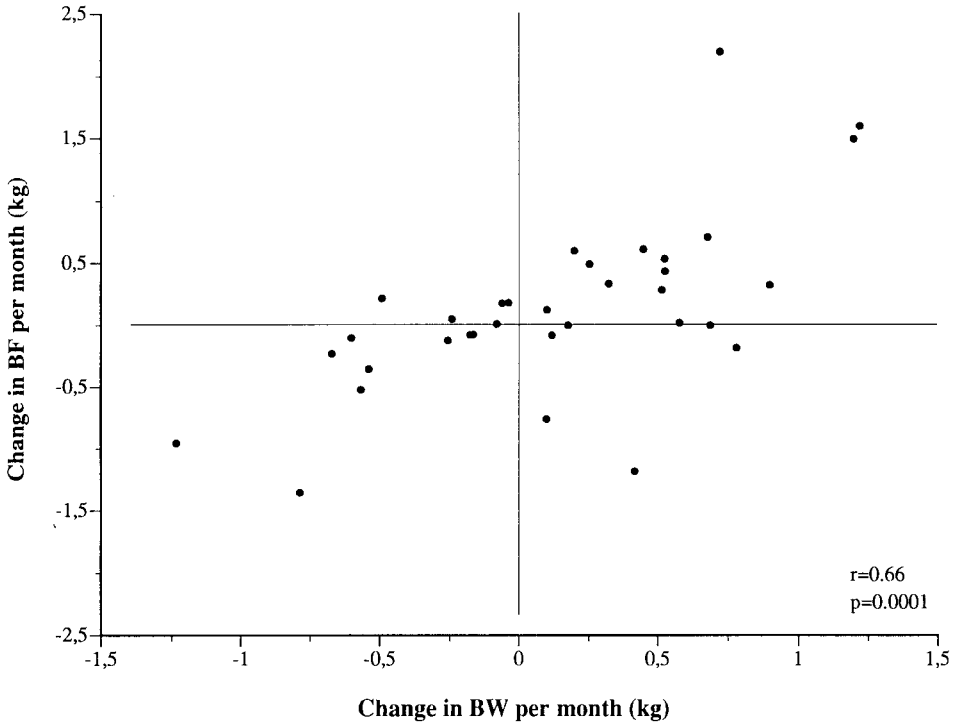


**Fig. 1.** Individual changes in BW in relation to changes in BF over time: early group.

Similar to the observations in the Early group, individual changes in BW correlated significantly with the individual changes in BF ($r=0.67$, $P=0.0004$), Figure 2a. However, in this Late group changes in BW also correlated with the individual changes in TBK ($r=0.66$, $P=0.0002$), Figure 2b, whereas there was no correlation between individual changes in BW and TBW (Table 3).

Although slightly lower, the serum albumin level at end of follow-up did not differ significantly from the baseline value (Table 2). The individual changes in serum albumin levels did not correlate with changes in TBK ($r=-0.06$; n.s.).

The total weekly creatinine clearance was 60.1 l/1.73 $m^2$ BSA (43–79 l) at the baseline examination (4–25.5 months after start of PD) and remained unchanged during follow-up, being 62.7 l/1.73 $m^2$ BSA (46–81 l) at the final examination. RRF at baseline was 1.2 ml/min/1.73 $m^2$ BSA (0–3.8) and 0.9 ml/min/1.73 $m^2$ BSA (0–3.5) at the end of follow-up.

Changes in RRF did not correlate with changes in BW, TBK, BF, TBW or serum albumin.

## Discussion

The main finding of this study was that total body potassium, reflecting body cell mass, decreased during long-term treatment with peritoneal dialysis, despite an adequate and stable dialysis efficacy. In contrast to the reduction in body cell mass, the patients accumulated body fat. There was also a lower than normal total body potassium at the start of dialysis. The nutritional consequences of uremia are further illustrated by the reduced body weight in the patients entering PD.

The results in this study were obtained from repeated determinations of body composition in PD patients. The study population was recruited from all patients treated with PD during a 3-year period in our department.

In comparison with all patients starting PD in Sweden during 1993–1995, the present study population had the same age and sex distribution, whereas the prevalence of diabetic nephropathy was slightly lower (Staffan Schöön, MD, The Swedish National EDTA Registry, personal communication). There were no major demographic differences between the patient study groups and the patients who did not undergo repeated determinations of body composition. The two study groups are therefore considered to be representative of adult Swedish PD patients.

The PD patient population has increased steadily in our department during the 1990s. This has lead to a stepwise introduction of a more structured management of the patients with specified and well defined treatment goals. This may be illustrated by the lower total weekly creatinine clearance in the Late group (in which most of the patients initiated their PD treatment before 1993) compared with the patients in the Early group. Therefore, it was deemed appropriate to analyse the patient population in these two separate patient groups. By analyzing changes in body composition over time, the maximum information from the total number of measurements is obtained, and the problems of different intervals between follow-up observations in individual patients are accounted for.

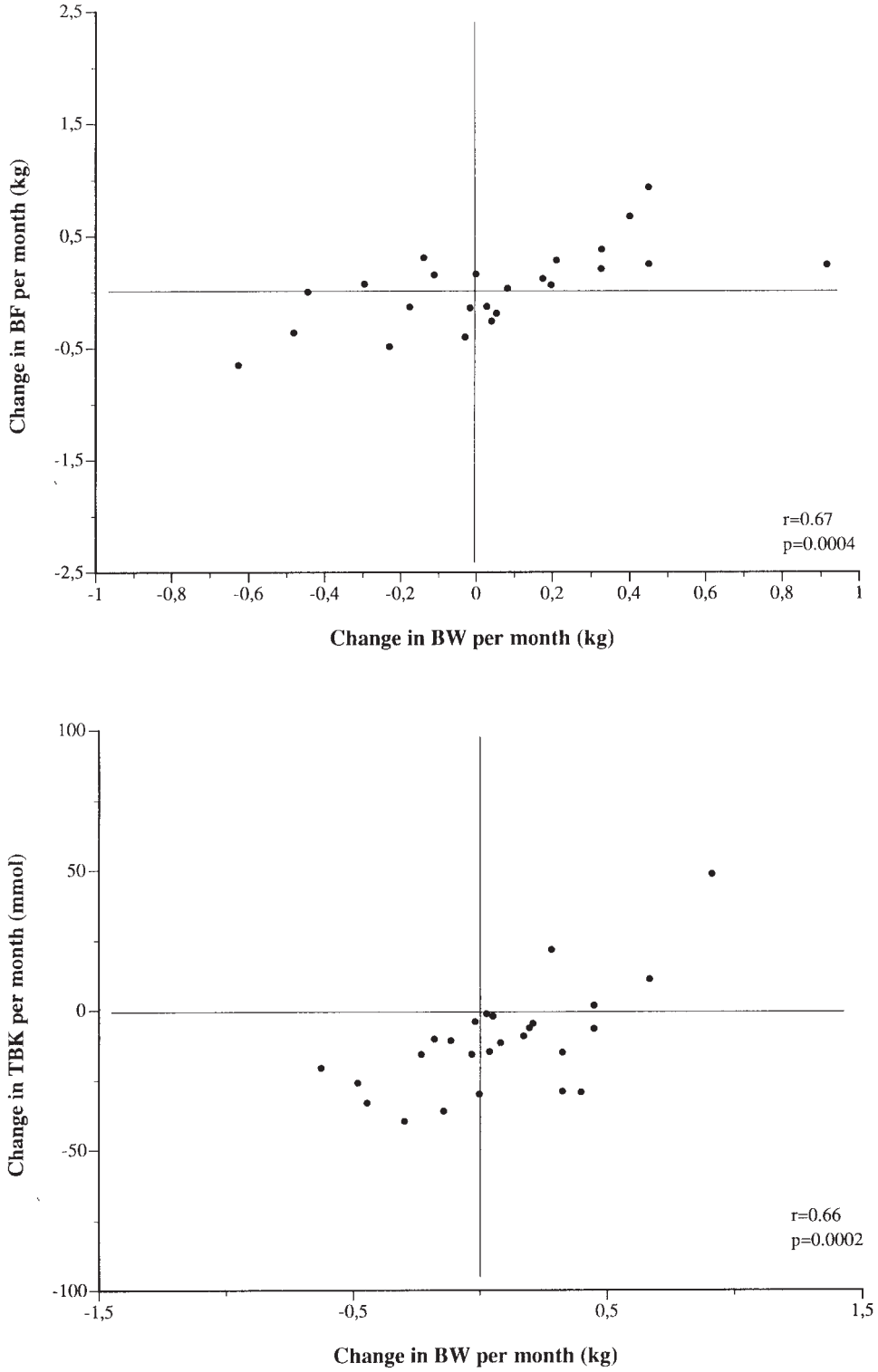


**Fig. 2.** (a) Individual changes in BW in relation to changes in BF over time: late group. (b) Individual changes in BW in relation to changes in TBK over time: late group.

As yet there is no ideal method for measuring nutritional status [17]. Repeated analyses of body composition permit longitudinal assessments of nutritional status and extend the information provided by short-term metabolic balance studies. Analysis of body composition by the four compartment model, as used in this study, might be preferred to two compartment models in patients with altered body hydration. Thereby, the concept of a constant composition of lean body mass (LBM) or fat-free mass is partially

circumvented. Methods assuming a constant composition of LBM have obvious limitations, since they do not accurately reflect variations in body cell mass in patients with alterations in extracellular volume, as in dialysis patients [18,19]. For the accurate determination of nutritional status, measurements of body cell mass, defined as 'the oxygen-exchanging, potassium-rich, glucose-oxidizing, work-performing tissue' [18], provide a more physiological variable.

Owing to the relation between the intracellular potassium and protein contents, measurements of total body potassium can be used as an index of the body cell mass [18]. Although the intracellular concentrations of potassium and the potassium/protein relation may be altered in severe disease states [20,21], available data from muscle biopsies and distribution of body water in patients with uremia indicate that in the patients monitored in the present study these variations are at most minor [22–24]. The body composition determinations were performed when the patients were in a stable clinical condition. Therefore, we consider that changes of TBK values in our patients adequately reflect changes in their body cell mass.

There is no available 'golden standard' for determining total body fat [17]. In the four compartment model, calculation of body fat is influenced by the measurement of total body water from the dilution of tritiated water. This method yields a slight overestimate of the true body water content, as the tritium undergoes exchange with nonaqueous hydrogen in the body [17]. However, this minor systematic error will affect all analyses equally and therefore will not interfere with the interpretation of relative changes over time. To avoid an erroneous influence of residual dialysate volume in the abdomen, TBW measurements were performed in the morning after drainage of the dialysate fluid. It must be pointed out, that one confounding factor may be a delayed gastric emptying in the PD patients [25]. This could result in falsely high values for TBW due to insufficient equilibration.

It is well documented that in large patient populations, the level of serum albumin strongly correlates to the clinical outcome in dialysis patients [4,26]. However, albumin levels are influenced by factors which are not directly related to nutrition [27,28]. This may explain the lack of correlation between the changes in TBK and serum albumin in the present study.

The patients in the Early group, with a moderate weight reduction at the start of dialysis, did not significantly increase their body weight during the first year of dialysis. This is at variance with several studies from other investigators, in which increases of body weight after initiation of PD have been reported [29–31]. One possible explanation for this discrepancy may be that the observation period of the Early group was too short. In the Late group, there was a clear tendency towards an increased BW at the last examination (Table 2), in comparison with BW at start of PD treatment (Table 1).

The correlation between individual changes in BW and BF in the Early group indicates that the weight gain in individual subjects during PD therapy is due to an increase in body fat.

While mean body cell mass remain unchanged during the first year of PD, the observation in the Late group suggests that there may be a decrease in body cell mass in patients during long-term PD treatment. During this period the patients appear to improve their energy balance slightly, which results in a moderate increase of body fat and thereby a maintained body weight. The reliability of this finding is illustrated by the similarity between the final values in the Early group compared with the baseline values in the Late group. The decrease of body cell mass was an almost consistent finding in the Late group and, hence, the reduction in muscle mass appears to be a general feature in patients during long-term PD treatment. This may be related to an insufficient compensation for the subsequent loss of RRF, as reflected by the lower total weekly clearance in the Late group compared with the Early group. It is plausible that a reduced total solute clearance may lead to an impaired appetite and, consequently, an insufficient food intake with a further deterioration of the nutritional status [32,33]. Continuous protein losses in the dialysate may also contribute to these negative long-term effects.

The catabolic effects of current infections, including peritonitis, reduced physical activity and other co-morbid conditions that result in inadequate food intake and/or increased protein catabolism should also be considered as important contributory factors for development of malnutrition. Davies *et al.* reported that patients with various co-morbid conditions and an increased need of dialysis frequently tend to receive an insufficient dose of dialysis [34].

Some studies of total body nitrogen (TBN) measurements have suggested that CAPD may infer an anabolic stimulus [35]. However, the results are conflicting. In early studies by the Toronto group, there was a fall in TBN while TBK increased or remained constant [30,31,36]. Thus, changes in TBN and TBK may reflect different processes during malnutrition and refeeding [21,37].

The present study clearly confirms our previous findings that patients with uremia, before, as well as during dialysis, have an altered body composition [10,11]. Some of the nutritional variables tend to deteriorate further during long-term PD treatment. This applies in particular to body cell mass. However, deviations from the normal are moderate in most patients. The optimal body composition in dialysis patients does not necessarily have to be identical to the body composition of healthy subjects. As pointed out by Blumenkrantz *et al.* [38], even patients who appear to be robust and doing well on dialysis have abnormal nutritional indices in comparison with healthy subjects. It is therefore important to identify the nutritional alterations that are caused by uremia *per se* and which of these that can be ameliorated by dialysis. It is equally important to identify the changes in nutritional status that are caused by nutritional inadequacies and those which are related to other co-morbid conditions.

PD is an efficient treatment for uremia with obvious

clinical and economical advantages. The absorption of glucose from dialysis fluid may facilitate the maintenance of body energy stores. However, the results of the present study indicate that some patients may be at risk of a deterioration of body cell mass during long-term treatment. Changes in body cell mass reflect changes in muscle mass and therefore have important clinical implications with regard to physical performance.

Further studies of important factors—patient related, dialysis related and others—for long-term nutritional status and their relation to quality of life, physical performance, morbidity and ultimately mortality are needed to evaluate the advantages and limitations of long-term peritoneal dialysis.

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