Eur J Cancer Clin Oncol, Vol. 23, No. 6, pp. 731–737, 1987.
Printed in Great Britain

0277–5379/87$3.00+0.00

Dissociation of Body Weight and Lean Body Mass during Cancer Chemotherapy

SIEBOLD S.N. DE GRAAF,* WILMA P. MEEUWSEN-VAN DER ROEST,† HEIMEN SCHRAFFORDT KOOPS‡ and WILLEM G. ZIJLSTRA†

**Division of Pediatric Oncology, Department of Pediatrics, †Department of Physiology, and ‡Division of Surgical Oncology, Department of Surgery, University of Groningen, P.O. Box 72, 9700 AB Groningen, The Netherlands*

Abstract—*Body weight and lean body mass are different reflections of the nutritional status of patients receiving cancer chemotherapy. In the present study, the relation between lean body mass and body weight during cytostatic treatment was investigated in 3 groups of newly-diagnosed children and young adults with acute lymphocytic leukemia, osteosarcoma, or a small round cell sarcoma. Body weight and lean body mass were determined before and after an initial period of cytostatic treatment. Lean body mass was derived from total body water volume, which was assessed by deuterium oxide dilution. A significant dissociation between body weight and lean body mass was observed in leukemia patients* (n = 8, P = 0.008, *paired t-test*), *and in osteosarcoma patients* (n = 13, P = 0.001). *No dissociation was found in patients with a small round cell sarcoma* (n = 8, P = 0.839). *We conclude that during cancer chemotherapy periodic assessment of body weight may give a false picture of the preservation of lean body mass. Considering the course of body weight alone may prevent the establishment of a timely diagnosis of malnutrition, which is mandatory for optimal supportive care.*

INTRODUCTION

THE PRESERVATION of a good nutritional status of the cancer patient is widely viewed as a major challenge. Increased energy expenditure and tumor-induced reduction of energy intake may result in a negative energy balance [1]. Food aversion due to chemotherapy may further contribute to the development of malnutrition [2]. The need for a timely diagnosis of malnutrition is generally acknowledged as this will identify patients who need additional nutritional support. Nutritional therapy may improve the patient's sense of well-being, increase the likelihood of a favorable response to tumor therapy, and decrease the morbidity associated with cancer treatment [3–6]. However, opinions are divergent on the question of how nutritional status should be evaluated [7]. A variety of objective measurements have been suggested, including assessments of serum albumin and transferrin, anthropometric evaluation, creatinine-height index, and determination of the cellular immune response [8, 9]. On the other hand, it has been suggested that simple clinical examination yields sufficient information on nutritional status, additional tests being redundant [10]. In clinical estimates of nutritional status, body weight is the most obvious and the most commonly used parameter. In patients who are treated with cancer chemotherapy, more than just a single nutritional assessment at diagnosis is required; longitudinal evaluation of nutritional status during treatment is also needed. In practice, this is often implemented by weighing the patient periodically.

The weight of the patient represents the sum of 2 major body compartments: body fat and lean body mass. The impact of these 2 components on the functioning of the subject is clearly different. Body fat mainly serves as an inactive energy reserve, whereas lean body mass contains the metabolically active cells and may be regarded as the 'functional part' of the body [7, 11]. Therefore, preservation of lean body mass deserves priority in the nutritional follow-up of cancer patients. However, it is not known to what extent the course of body weight reliably reflects the status of lean body mass in longitudinal evaluation during cancer chemotherapy. We are not aware of any study of children and young adults in which an attempt has been

Accepted 24 November 1986.
This study was supported by the Groningen Foundation for Pediatric Oncology.
Correspondence to S.S.N. de Graaf, Division of Pediatric Oncology, Department of Pediatrics, University of Groningen, P.O. Box 72, 9700 AB Groningen, The Netherlands.

made to determine whether the ratio between lean body mass and body weight remains stable during cytostatic treatment.

In the present paper we report on a study of the relation between lean body mass and body weight prior to, and after, an initial period of chemotherapy in a group of young cancer patients who were being treated at the Pediatric Oncology Center in Groningen, the Netherlands.

MATERIALS AND METHODS

Patients

Twenty-nine newly-diagnosed patients, 16 male and 13 female, aged 3–37 years (median 13), were investigated. Patients were suffering from acute lymphocytic leukemia, osteosarcoma, Ewing's sarcoma, or rhabdomyosarcoma. Diagnoses were established by microscopic examination of bone marrow or a biopsy specimen. In each case verbal informed consent was obtained from patient and/or parents. At the time of their participation in the study, all patients were treated with chemotherapy depending on the diagnostic group to which they belonged. Group 1 consisted of 8 patients with acute lymphocytic leukemia, 4 male and 4 female, aged 4–13, median 7 years. They were receiving the first part of remission induction therapy according to the current protocol of the Dutch Childhood Leukemia Study Group [12], which included daily prednisone 40 mg/m^2 orally, and weekly vincristine 2 mg/m^2 intravenously; 4 patients in this group were also given daunomycin in weekly intravenous dosages of 25 mg/m^2. Group 2 consisted of 13 patients with osteosarcoma, 6 male and 7 female, aged 11–37, median 17 years. These patients received 4 weekly doses of methotrexate, 12 g/m^2, followed by leucovorin rescue as preoperative therapy before amputation or limb salvage procedure [13]. Group 3 consisted of 8 patients, 6 male and 2 female, suffering from a small round cell sarcoma, either Ewing's sarcoma or rhabdomyosarcoma. Age range in this group was 3–24, median 10 years. They were treated with repetitive courses of combination chemotherapy, consisting of vincristine, bleomycin, methotrexate, doxorubicin, actinomycin D, and cyclophosphamide, according to the Memorial Sloan Kettering Hospital protocol T-9 [14]. None of the patients underwent surgical tumor resection or radiation therapy before or during the study period.

Patients in groups 1 and 2 were hospitalized during the study period, group 3 patients were treated largely as out-patients. Routinely, all patients were encouraged to eat well in spite of anorexia, and protein and energy-enriched food was advised. If oral food intake was judged to be insufficient, additional feeding by nasogastric tube was given. Parenteral nutrition was not used. In patients with acute lymphocytic leukemia total intestinal decontamination in combination with sterilized food was used for the prevention of enterogeneous infections [15].

Study design

In each patient 2 measurements of body weight, lean body mass, and plasma osmolality were performed. The first measurement was carried out as soon as the clinical diagnosis was established, prior to the beginning of therapy. The second measurement was scheduled after the first part of chemotherapy. The exact time point at which the second measurement was carried out depended on the chemotherapy protocol and was consistently chosen in each patient group. In group 1, the leukemia patients, the second measurement was performed after about 4 weeks (median 27 days). In this interval prednisone was administered continuously. As the scope of the present study was focused on chemotherapy effects, the second measurement in the osteosarcoma patients, group 2, was performed prior to the surgical resection, which was scheduled after 4 courses of high-dose methotrexate. Thus, the second measurement was carried out shortly before surgery, at a time when the patient was judged to be in a stable condition. The median interval between the measurements in the osteosarcoma patients was 38 days. In the group 3 patients, who were being treated according to the T-9 polychemotherapy protocol for small round cell sarcoma [14], the second measurement was performed before the start of the second cycle of chemotherapy, after the patient had recovered from the acute toxicity due to the preceding phase of drug administration. In this group the median interval between measurements was 62 days.

Measurements

Lean body mass was derived from total body water volume, which in turn was determined by indicator dilution using deuterium oxide (D_2O), as previously reported [16]. A bolus of D_2O 99.75% (E. Merck Nederland B.V., Amsterdam) in a dosage of 1 ml per kg body mass was administered intravenously. The amount of indicator actually added was assessed by weighing the syringe before and after the injection. Blood samples were taken at time 45, 60 and 75 min. D_2O was measured in erythrocyte water by means of infrared spectrophotometry. First, 0.5 ml of erythrocytes was vacuum-sublimated to near total dryness. The condensate was collected in traps immersed in liquid nitrogen. The absorbance of the condensate at a wave number $\lambda^{-1} = 2486\ cm^{-1}$ was determined by means of a Perkin–Elmer 177 infrared spectrophotometer. A sealed liquid cell with CaF_2 windows and a lightpath

length of 0.01 cm was used. A piece of ordinary window glass having the same absorption as a water-filled cell at the measuring wavelength was used in the reference beam. The measured absorbances were converted into D_2O concentrations using a calibration line specially made for each series of determinations. D_2O elimination being monoexponential during the sampling period, the indicator concentration at time zero could be obtained by extrapolation. Total body water volume was then calculated by dividing the amount of indicator injected by its concentration at time zero. Finally, lean body mass was derived from total body water volume by dividing by 0.73 [7, 8, 17, 18].

Body weight of the patients was determined on a Seca electronic balance to the nearest 0.1 kg. The patients were clothed in light underwear only. Plasma osmolality measurements were performed using a Knauer Halbmikro Osmometer.

Data from the first and second measurements were compared by means of the paired Student's *t*-test.

RESULTS

At the time of the first measurement, nutritional status as judged by weight and height appeared within the normal range in all patients except in 2 female patients having osteosarcoma. One of them was manifestly obese, her weight lying considerably above the 90th centile; the other was overtly malnourished, her weight being below the 10th centile. In all other patients, body weight by height lay between the 10th and 90th centiles.

In the majority of patients in this study, the malignant process responded favorably to cytostatic treatment. All leukemia patients had attained a complete remission at the end of the induction treatment. Among the 13 patients suffering from osteosarcoma, the soft tissue extension of the tumor showed a decrease in volume in 5 of them, and in 6 patients it remained stable. In 2 osteosarcoma patients the tumor was progressive in the interval between the measurements. The patients with a small round cell sarcoma all showed definite tumor shrinkage in response to therapy.

All patients received additional feeding by nasogastric drip for some period of time, either on the ward or at home, when oral food intake was judged insufficient by the physician in charge. Quantitative data on energy balance have not been recorded.

In none of the patients was any disturbance of fluid homeostasis clinically manifest. Diarrhea or excessive vomiting did not occur on the days preceding the measurements. No sudden change in body weight, attributable to acute fluid retention or depletion, was noted during these days. Edema or effusions were not clinically detectable.

Table 1 gives the data from the 8 patients with acute lymphocytic leukemia. In this group, mean body weight increased slightly, while total body water volume and the calculated lean body mass showed some decrease, neither of these shifts being statistically significant. Even so, the ratio of lean body mass and body weight decreased significantly. The slight decrease in plasma osmolality is not significant.

The results of the measurements in group 2, consisting of 13 patients with osteosarcoma, are given in Table 2. There is a significant loss of body weight, but the deterioration of lean body mass is even more severe. This is also reflected by the significant decrease in the lean body mass/body weight ratio. During chemotherapy lean body mass diminished by about 10%, considerably more than predicted by the course of body weight.

The data of the patients with a small round cell sarcoma, group 3, are presented in Table 3. At the end of the first cycle of cytostatic treatment, neither body weight nor lean body mass had changed significantly. As opposed to the results in group 1 and 2, in the group 3 patients the ratio between lean body mass and body weight remained constant.

DISCUSSION

It is well documented that malignancy may have an impact on body composition [19, 20]. However, little is known about the possible impact of cancer chemotherapy on distinct compartments of the patient's body. In the present study, we investigated whether the ratio between lean body mass and body weight remains constant during cytostatic treatment.

For the measurement of lean body mass no standard method exists, so divergent techniques for its approximation are in use [21]. Measurements of skinfold thickness are used to estimate total body fat [22–24]. Lean body mass is then calculated as the difference between body weight and estimated body fat. Skinfold measuring may be a useful method, but it is difficult to assure good reproducibility of the results [24]. Lean body mass can also be estimated through determination of body density by underwater weighing. Obviously, this method is not particularly suitable for clinical application. Finally, as the water content of lean body mass is constant, and body fat contains little water, lean body mass can be estimated by measuring total body water volume. Each technique has its specific characteristics, and measurements of lean body mass using different methods will not necessarily yield the same results [21, 25].

In the present study, lean body mass was derived from total body water volume, measured by means of D_2O dilution. D_2O contains a stable hydrogen isotope, is not toxic in the dose used, and its concen-

Table 1. Body weight, total body water volume, lean body mass, and plasma osmolality in 8 patients with acute lymphocytic leukemia

		1st evaluation	2nd evaluation	Difference	*P*-value*
Body weight	(kg)	27.0 ± 2.8†	27.5 ± 2.7	0.5 ± 0.3	0.191
Total body water	(l)	17.1 ± 1.8	16.3 ± 1.9	−0.8 ± 0.4	0.097
Lean body mass	(kg)	23.5 ± 2.5	22.3 ± 2.6	−1.2 ± 0.6	0.097
Lean body mass/body weight		0.87 ± 0.02	0.80 ± 0.02	−0.07 ± 0.02	0.008
Plasma osmolality	(mmol/kg)	283 ± 1	280 ± 1	−3 ± 1	0.084

*Paired Student's *t*-tests.
†Mean values ± standard error.

Table 2. Body weight, total body water volume, lean body mass, and plasma osmolality in 13 patients with osteosarcoma

		1st evaluation	2nd evaluation	Difference	*P*-value*
Body weight	(kg)	60.5 ± 4.5†	58.1 ± 4.5	−2.4 ± 0.9	0.018
Total body water	(l)	35.6 ± 2.3	32.1 ± 2.2	−3.5 ± 0.7	< 0.001
Lean body mass	(kg)	48.8 ± 3.2	44.0 ± 3.0	−4.8 ± 0.9	< 0.001
Lean body mass/body weight		0.82 ± 0.02	0.77 ± 0.02	−0.05 ± 0.01	< 0.001
Plasma osmolality	(mmol/kg)	284 ± 2	284 ± 2	0 ± 3	0.911

*Paired Student's *t*-tests.
†Mean values ± standard error.

Table 3. Body weight, total body water volume, lean body mass, and plasma osmolality in 8 patients with a small round cell sarcoma

		1st evaluation	2nd evaluation	Difference	*P*-value*
Body weight	(kg)	41.1 ± 7.9†	42.0 ± 8.0	0.9 ± 0.8	0.346
Total body water	(l)	24.0 ± 4.2	24.6 ± 4.4	0.6 ± 0.7	0.352
Lean body mass	(kg)	32.8 ± 5.7	33.7 ± 6.1	0.9 ± 0.9	0.352
Lean body mass/body weight		0.83 ± 0.04	0.83 ± 0.04	0.00 ± 0.02	0.839
Plasma osmolality	(mmol/kg)	283 ± 3	286 ± 3	3 ± 3	0.336

*Paired Student's *t*-tests.
†Mean values ± standard error.

tration in biological fluids can be measured accurately using infrared spectrophotometry. Red cells were used for the determination of D_2O concentration so that plasma was saved for other measurements. The feasibility and accuracy of the method used have been confirmed in previous experiments [16].

The values of lean body mass presented in the results section have been calculated from total body water volume using the reportedly constant water content of lean body mass: 73% of lean body mass is water [7, 8, 17, 18]. Another way of calculating lean body mass from total body water volume could be based on the concepts of Morse and Soeldner [26]. Lean body mass is then calculated using the equation: lean body mass equals 1.85 times the mass of total body water minus 0.28 times body weight. We applied this approach also to the calculation of lean body mass in our patients. The essentials of these alternative calculations are consolidated in Table 4 and appear to confirm the data shown in Tables 1–3.

In adolescents and children the water content of lean body mass may be slightly higher than in adults, but a significant increase of water content is only present in neonates [11, 17, 27, 28]. The patients in our study did not include infants, and therefore only minor variations in water content of

Table 4. Ratio of lean body mass, calculated according to Morse and Soeldner [26], *and body weight*

		1st evaluation	2nd evaluation	Difference	*P*-value*
Leukemia group	(n = 8)	0.89 ± 0.02†	0.81 ± 0.03	−0.08 ± 0.02	0.008
Osteosarcoma group	(n = 13)	0.82 ± 0.03	0.76 ± 0.03	−0.06 ± 0.01	< 0.001
Small round cell sarcoma group	(n = 8)	0.84 ± 0.05	0.84 ± 0.05	0.00 ± 0.03	0.839

*Paired Student's t-tests.
†Mean values ± standard error.

lean body mass may have been present. More importantly, by the paired design of the study, the measurements in each patient were compared with previously recorded data in the same individual. In this way, variation of water content as a function of age is eliminated as a possible interfering factor in the interpretation of the results. In the patients studied, no disturbance of hydration status was clinically manifest at either of the 2 measurements. Plasma osmolality did not change significantly in any of the groups.

Cancer has been associated with an increased water content of the host [29]. In the interval between our measurements, the malignant process responded favorably to therapy in the majority of patients. One might therefore argue that the decrease in the ratio between lean body mass and body weight reflects the reduction of tumor-induced hyperhydration. A second comment might be that the observed shifts are simply the result of a chemotherapy-induced loss of 'lean tumor mass'. Our results do not support these hypotheses. First of all, the patients with a small cell sarcoma had a clinically significant decrease in tumor burden. Yet, in this group no change in either body weight or lean body mass was detected. Secondly, the decrease of the lean body mass/body weight ratio was most significant in the osteosarcoma patients, in whom tumor shrinkage was much less evident. Thus, it does not seem rational to explain the decrease in relative body water volume by a reduction of cancer-induced hyperhydration, or simply by a loss of tumor mass.

The patients in this study generally experienced difficulties with normal food intake. In group 2 and 3 patients, the intensive chemotherapy regimens can be held accountable for anorexia and nausea, leading to insufficient oral food intake [30]. In the leukemia patients, the reason for a lack of appetite is less obvious: they were receiving prednisone, a drug which often stimulates food intake. However, these patients were also given total intestinal decontamination and sterilized food [15]. The unpalatable oral non-absorbable antibiotics used in this regimen presumably played a major part in the loss of appetite in group 1 patients. Additional feeding by nasogastric tube was utilized in all patients with the intention of preserving nutritional status.

The results of the present study demonstrate that during cancer chemotherapy a significant dissociation between body weight and lean body mass may occur. This means that the degree of preservation of lean body mass during cytostatic treatment is not reliably reflected by the course of body weight. Using body weight as the only parameter for nutritional follow-up, the clinician may obtain a falsely optimistic picture of the preservation of lean body mass. Furthermore, the course of lean body mass cannot readily be predicted from body weight since the dissociation between body weight and lean body mass apparently may vary among groups of patients who are being treated with different chemotherapy regimens.

A more than proportional reduction of lean body mass must be associated with a relative increase in body fat. Apparently, a relatively large portion of energy intake is converted to body fat. In group 1 patients this may at least be partly due to prednisone. This drug is a major component in the initial treatment of acute lymphocytic leukemia and is known to have extensive metabolic effects. The turnover of glucose is increased, more of it being metabolized to fat [31]. It is conceivable that these metabolic effects of prednisone have had an impact on the ratio of body weight and lean body mass. One might speculate that other cytostatic agents may also interfere with energy disposal in some way, eventually resulting in accumulation of fat. In the group 3 patients no change in the ratio between body weight and lean body mass was detected. In these patients the interval between the measurements was considerably longer than in groups 1 and 2. Moreover, there was a delay of at least 2 weeks between the last infusion of chemotherapeutic agents and the second assessment of body weight and lean body mass. It is possible that during this interval the patients recovered from drug-induced changes of body composition that might have been present at an earlier stage.

Our results are consistent with those of Shike *et al.* [32], who investigated body composition in patients receiving chemotherapy for small cell lung

cancer. These authors reported an increase in body weight during total parenteral nutrition, which was mainly due to accumulation of fat. Also in our study a major part of energy intake is apparently converted to body fat.

In conclusion, our results suggest that periodic weighing of the patient is insufficient for appropriate monitoring of nutritional status during cancer chemotherapy. Use of additional parameters should be considered. Which of the methods currently available for nutritional assessment should be given preference for longitudinal evaluation during cytostatic treatment has yet to be established. Our experience suggests that the assessment of lean body mass by means of D_2O dilution is convenient for the patient, is relatively simple to perform, and may yield clinically valuable information.

Acknowledgements—The authors thank the nursing staff of the pediatric department for their assistance in collecting blood samples.

REFERENCES

1. DeWys WD. Pathophysiology of cancer cachexia: current understanding and areas for future research. *Cancer Res* 1982, **42** (suppl), 721s–726s.
2. Bernstein IL. Physiological and psychological mechanisms of cancer anorexia. *Cancer Res* 1982, **42** (suppl), 715s–720s.
3. Hoffman-Goetz L, Blackburn GL. Relationship of nutrition to immunology and cancer. In: Newell GR, Ellison NM, eds. *Nutrition and Cancer, Etiology and Treatment.* New York, Raven Press, 1981, 73–92.
4. Donaldson SS, Wesley MN, DeWys WD, *et al.* A study of the nutritional status of pediatric cancer patients. *Am J Dis Child* 1981, **135**, 1107–1112.
5. Donaldson SS. Effect of nutritional status on response to therapy. *Cancer Res* 1982, **42** (suppl), 754s–755s.
6. Van Eys J. Effect of nutritional status on response to therapy. *Cancer Res* 1982, **42** (suppl), 747s–753s.
7. Shizgal HM. Body composition of patients with malnutrition and cancer. Summary of methods of assessment. *Cancer* 1985, **55** (suppl), 250–253.
8. Blackburn GL, Bothe A. Assessment of malnutrition in cancer patients. *Cancer Bull* 1978, **30**, 88–93.
9. Burritt MF, Anderson CF. Laboratory assessment of nutritional status. *Hum Pathol* 1984, **15**, 130–133.
10. Baker JP, Detsky AS, Wesson DE, *et al.* Nutritional assessment: a comparison of clinical judgment and objective measurements. *N Engl J Med* 182, **306**, 969–972.
11. Friis-Hansen B. Water distribution in the foetus and newborn infant. *Acta Paediatr Scand* 1983, **305** (suppl), 7–11.
12. Van der Does-Van den Berg A, Van Wering ER, De Koning J, *et al.* Addition of rubidomycin to induction treatment with vincristine, prednisone and L-asparaginase in standard-risk childhood acute lymphocytic leukemia. *Leukemia Res* 1986, **10**, 112.
13. Rosen G, Caparros B, Huvos AG, *et al.* Preoperative chemotherapy for osteogenic sarcoma: selection of post-operative adjuvant chemotherapy based on the response of the primary tumor to preoperative chemotherapy. *Cancer* 1982, **49**, 1221–1230.
14. Rosen G, Caparros B, Nirenberg A, *et al.* Ewing's sarcoma: ten years' experience with adjuvant chemotherapy. *Cancer* 1981, **47**, 2204–2213.
15. De Graaf SSN, Dankert J, Akkerboom JC. Total bowel flora suppression in children with ALL. *Proc Am Soc Clin Oncol* 1985, **21**, 274.
16. Zweens J, Frankena H, Reicher A, Zijlstra WG. Infrared-spectrometric determination of D_2O in biological fluids. *Pflügers Arch* 1980, **385**, 71–77.
17. Haschke F. Body composition of adolescent males. *Acta Paediatr Scand* 1982, **307** (suppl), 3–23.
18. Pace H, Rathburn EN. Studies in body composition: III. The body water and chemically combined nitrogen content in relation to fat content. *J Biol Chem* 1945, **158**, 685–691.
19. Craig AB, Waterhouse C. Body composition changes in patients with advanced cancer. *Cancer* 1957, **10**, 1106–1109.
20. Warnold I, Lundholm K, Schersten T. Energy balance and body composition in cancer patients. *Cancer Res* 1978, **38**, 1801–1807.
21. Almond DJ, King RF, Burkinshaw L, Oxby CB, McMahon MJ. Measurement of short term changes in the fat content of the body: a comparison of three methods in patients receiving intravenous nutrition. *Br J Nutr* 1984, **52**, 215–225.
22. Brook CGD. Determination of body composition from skinfold measurements. *Arch Dis Child* 1971, **46**, 182–184.
23. Durnin JGVA, Womersley J. The assessment of the total amount of fat in the human body from measurements of skinfold thickness. *Br J Nutr* 1971, **32**, 77–79.
24. Neumann CG, Jelliffe DB, Zerfas AJ, Jelliffe EFP. Nutritional assessment of the child with cancer. *Cancer Res* 1982, **42** (suppl), 699s–712s.
25. Cohn SH, Ellis KJ, Vartsky D, *et al.* Comparison of method of estimating body fat in normal subjects and cancer patients. *Am J Clin Nutr* 1981, **34**, 2839–2847.

26. Morse WI, Soeldner JS. The measurement of human adipose tissue mass. In: Renold AE, Cahill Jr GF, eds. *Handbook of Physiology, Section 5: Adipose Tissue.* Baltimore, William & Wilkins, 1965, 653–659.
27. Friis-Hansen B. Changes in body water compartments during growth. *Acta Paedriatr Scand* 1957, **110** (suppl), 1–68.
28. Van der Wagen A, Okken A, Zweens J, Zijlstra WG. Body composition at birth of growth-retarded newborn infants demonstrating catch-up growth in the first year of life. *Biol Neonate* 1986, **49**, 121–125.
29. Watson WS, Sammon AM. Body composition in cachexia resulting from malignant and non-malignant diseases. *Cancer* 1980, **46**, 2041–2046.
30. Kokal WA. The impact of antitumor therapy on nutrition. *Cancer* 1985, **55** (suppl), 273–278.
31. Von Eickstedt KW. Corticotrophins and corticosteroids. In: Dukes NMG, ed. *Meyler's Side Effects of Drugs.* Amsterdam, Elsevier, 1984, 730–742.
32. Shike M, Russel DM, Detsky AS, *et al.* Changes in body composition in patients with small cell lung cancer. The effect of total parenteral nutrition as an adjunct to chemotherapy. *Ann Intern Med* 1984, **101**, 303–309.