Energy intake and expenditure in elderly patients admitted to hospital with acute illness

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Studies on hospitalized elderly subjects have demonstrated that negative energy balance is common during hospitalization, but have concentrated primarily on long-stay and psychogeriatric patients. There is little information on energy balance in elderly patients admitted with acute illness from the community, despite the importance of this patient group and the presence of a number of factors likely to predispose such patients to negative energy balance. In the present study energy balance was quantified in twenty patients (eight males, mean age 82 (SD 5) years; twelve females, mean age 84 (SD 6) years) admitted from the community with acute illness, and predicted basal metabolic rate (BMR) was compared with measured resting metabolic rate (RMR). Most patients were in negative energy balance during hospitalization, and median measured energy intake (EI):measured RMR ratio was 1·0 (range 0·7–1·8). The mean difference between measured EI and estimated total energy expenditure was −1·3 MJ/d (range −3·4 to +2·5 MJ/d). Estimated total energy expenditure exceeded measured EI in fifteen of the patients and there was a significant decline in mid-arm muscle circumference (paired *t*, $P < 0.05$) during hospitalization. We conclude that moderate negative energy balance is common in this patient group, and that these patients are at risk of undernutrition during their hospital stay.

Acute illness: Elderly: Energy metabolism

Undernutrition is established as the major nutritional issue in the care of the elderly (Lehmann, 1989; Department of Health, 1992). Undernutrition in any patient population leads to an increase in morbidity and mortality via a range of effects on physiological and biochemical systems (Sullivan *et al.* 1990; Kings Fund Centre, 1992). A relatively high proportion of long-stay and psychogeriatric patients are undernourished (Morgan *et al.* 1986), and there is good evidence that the nutritional status of many such patients shows progressive or episodic deterioration during hospitalization (e.g. Prentice *et al.* 1989; Larsson *et al.* 1990). Negative energy balance is therefore common in the long-stay and psychogeriatric setting (e.g. Prentice *et al.* 1989; Sutherland & Wooton, 1993), but there is little evidence for its prevalence in elderly patients admitted with acute illness from the community. Factors which are known to predispose to negative energy balance such as reduced appetite, feeding or eating difficulties, and increased basal metabolic rate (BMR) associated with infection (Hodkinson, 1988) are all common in this patient group and it might therefore be expected that negative energy balance is common.

Application of energy balance techniques, i.e. measurements of energy intake (EI) and expenditure (BMR and/or total energy expenditure, TEE), can reveal subtle aspects of nutritional inadequacy before these become demonstrable using more crude indices such as weight loss (Hodkinson, 1988). These techniques can therefore predict weight loss and

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deterioration in nutritional status in individual patients or groups of patients, and can act as criteria against which to judge the adequacy of nutritional provision in hospital, particularly during relatively short hospital stays. Evidence from changes in anthropometric variables can confirm the prediction of negative energy balance, but anthropometric indices such as body weight are crude and insensitive indices of nutritional adequacy in the short term.

If undernutrition and negative energy balance are to be corrected, some clinical means of assessing the energy requirement of an individual patient is desirable. For most elderly inpatients BMR will represent the major component of TEE, perhaps up to 80% of TEE (Reilly *et al.* 1992), and so prediction of BMR is a logical first step in the estimation of energy requirement. At present the recommended approach here is to estimate BMR using equations based on age, sex, and body weight, derived from samples of largely younger (60–70 years) healthy elderly subjects (Department of Health, 1992). These equations are intended for groups rather than individuals, but are commonly used to predict BMR of individuals and have some practical utility when used in clinical setting, for example in determining the diet prescription for nutritional support. Once BMR is estimated, a physical activity level (arguably 1·2–1·4 for the hospitalized elderly) is used to estimate TEE. The validity of a variety of equations for prediction of BMR in younger adults has recently been called into question (Clark & Hoffer, 1991) for a variety of reasons, but principally that differences in methodology, study protocol, or subjects selected might mean that predictive equations entail systematic errors when cross-validated. This debate has largely excluded considerations of BMR in the elderly, but it is possible to make a theoretical case which suggests that the predictive equations currently recommended for use in the UK have either large biases or large random errors when applied to individual elderly patients. Additional information on the magnitude and direction of errors observed in attempting to predict BMR of elderly patients is therefore desirable. The aim of the present study was to quantify energy balance in a group of elderly patients randomly selected from a sample of patients included in a nutritional survey of acute admissions to a geriatric unit.

METHODS

Patients

Subjects in the present study (*n* 20; eight males, twelve females) represented a randomly selected sub-sample of a cohort of patients (*n* 77) participating in a survey of nutritional status of consecutive acute admissions to a geriatric unit. The cohort was selected randomly from consecutive admissions over a 4-month period. The results of the nutritional survey will be reported in a separate communication. Only patients admitted directly from their own homes as emergency admissions were included. The hospital receives emergency admissions directly from the community following GP referral, and the unit concerned has high patient turnover: 85% of patients currently regain independent mobility and are discharged home within 3–4 weeks. Patients were excluded if they suffered severe cognitive impairment and were unable to give informed consent to the study, or if they had a known neoplastic condition on admission. All subjects gave informed consent to the procedures described and the research was approved by the local Ethics Committee.

Anthropometric assessments

Body weight was measured to 0·1 kg in hospital gown, without shoes, in the morning and after emptying the bladder. A digital electronic wheelchair scale (SECA, Birmingham) was necessary for measurement of weight. Stature could not be measured accurately or reliably in these patients and so was predicted from knee height (distance between the sole of the foot and apex of knee with each joint flexed at an angle of 90°) using the equations given by Chumlea *et al.* (1985):

$$\text{in men, height (cm)} = 60{\cdot}45 + (\text{knee height} \times 2{\cdot}04),$$

$$\text{in women, height (cm)} = 84{\cdot}88\ (\text{knee height} \times 1{\cdot}83) - (0{\cdot}24 \times \text{age, years}).$$

These predictive equations can entail quite large errors in predicted height in individuals, but mean differences between measured and predicted height are typically < 2 cm (Cockram & Baumgartner, 1990; Haboubi *et al.* 1990). Error of this magnitude is unlikely to lead to serious error in classification of patients based on body mass index (BMI). Lack of evidence of bias in the prediction (Cockram & Baumgartner, 1990; Haboubi *et al.* 1990), and the high degree of cross-validity to other elderly groups including hospitalized elderly in the UK (Haboubi *et al.* 1990) suggest that bias in nutritional assessment based on BMI derived from predicted height is unlikely. Furthermore, intra-observer reliability is high and when used for changes in BMI the question of the knee-height measurement itself becomes relatively unimportant (Chumlea *et al.* 1985; Cockram & Baumgartner, 1990). Predicted stature was used to calculate BMI and anthropometric assessment of nutritional status based on BMI relative to appropriate reference values (Burr & Phillips, 1984). The circumference of the upper arm was determined with a flexible non-stretch tape measure to 1 mm at the measured mid-point (between acromion and olecranon) on the non-dominant side. Mid-upper arm muscle circumference (MAMC) was calculated as:

$$\text{MAMC (mm)} = (\text{mid-arm circumference, mm}) - (3{\cdot}14 \times \text{triceps skinfold, mm}).$$

Accuracy and reproducibility of the mid-arm circumference and triceps skinfold measurements (as well as the other three skinfolds measured) were established in a pilot study before undertaking the work presented here (K. Klipstein-Grobusch, unpublished results). Anthropometric assessments were carried out on admission, and at 2, 4, and 6 weeks of hospitalization, or to hospital discharge if this occurred before 6 weeks. For one of the patients discharge occurred at 10 d post-admission and in this case all measurements were carried out on the day before discharge.

Measurement of body composition

Body composition (fat mass, fat-free mass) was determined by estimation of body density using the sum of four skinfolds (Durnin & Womersley, 1974). Prediction of body density from skinfolds appears to be associated with a small bias in elderly women, though apparently not in elderly men (Reilly *et al.* 1993*b*). However, the bias is of negligible practical significance and measurement of skinfolds remains a method which is at least as valid as other methods (and more valid than some), in both younger adults (Fuller *et al.* 1992) and the elderly (Reilly *et al.* 1994). Furthermore, skinfolds appear to be no less valid than any other method for the estimation of changes in body composition (Jebb *et al.* 1993).

Measurement of resting metabolic rate (RMR)

RMR was measured in thirteen of the twenty patients on at least two occasions: within 48 h of admission, and again at 14 d post-admission (±48 h). In the other seven patients the first two measurements of RMR were made within 48 h of admission and at 14 d post-admission, and a third measurement was made at 28 d post admission (±24 h). In one of the twenty patients, tolerance of the RMR measurement was poor on each occasion and, since the quality of the data obtained was in serious doubt, the data for this patient (number 6) were rejected and predicted BMR used. In all the other patients tolerance of the measurement was good on every occasion. Individual data for measured RMR are presented, together with means for each individual, since in general there was little evidence of differences between RMR measurements with time which were of practical significance within individuals (see Table 3). In ten of the patients, measured RMR differed by > 0·2 MJ/d from first to last measurement (five increases, five decreases). In the other nine the change from first to last measurement was within 0·2 MJ/d. For the seven patients with three measurements, mean coefficient of variation of BMR was 7 % (range 3·7–14·4) %. The rationale for the timing of BMR measurements was that energy balance should be 'sampled' at various stages during hospitalization, with the difficulty that the precise duration of hospitalization (and clinical outcome) could not be predicted at admission in these patients admitted with acute illness. Furthermore, the nature of possible changes in BMR during hospitalization was unknown and not readily predictable at the beginning of the study. Given the lack of marked changes in RMR during hospitalization, and the absence of evidence of systematic change (see Table 3) it was considered justifiable to use mean measured RMR for each patient in the energy balance calculations (and mean of individual daily energy intake measurements for the same reasons).

Measurement of RMR was made using a ventilated-hood indirect calorimeter (Deltatrac; Datex Instrumentarium Corporation, Helsinki, Finland). Before undertaking the study, the validity of the measurement of V_{O_2} and V_{CO_2} by the instrument was determined by infusion of a test gas of known composition (N_2–CO_2; 80:20 v/v) at measured rates of flow which simulated physiological rates of O_2 consumption and CO_2 production (Reilly *et al.* 1993*a*). In addition, a quantitative alcohol burning test was carried out before the study as a check on the flow rate of the instrument (fixed at 39·8 litres/min). Immediately before each RMR measurement the calorimeter was calibrated twice using a reference gas mixture (O_2–CO_2, 95:5 v/v; Datex Instrumentarium Corporation).

Each individual measurement of RMR lasted for a minimum of 30 min (typically 40–45 min) and followed an overnight bed rest and a period of 30 min at complete rest in bed. Rates of O_2 consumption and CO_2 production reached a 'steady state' in all cases (except patient 6) within 10 min of the beginning of the procedure and minute-by-minute data used to calculate RMR were taken as the mean of the remaining 25–35 min of each measurement. Measurements are referred to here as RMR because patients were ill, but measurement conditions otherwise met all the criteria for measurement of basal metabolism, as classically defined (Dubois & Dubois, 1936).

Prediction of basal metabolic rate

In all subjects BMR was predicted using the appropriate equation from the recent report, *The Nutrition of Elderly People* (Department of Health, 1992):

males: 60–74 years BMR (MJ/d) = $0{\cdot}0499W + 2{\cdot}930$,

> 75 years BMR (MJ/d) = $0{\cdot}0350W + 3{\cdot}434$;

females: 60–74 years BMR (MJ/d) = $0{\cdot}0386W + 2{\cdot}875$,

> 75 years BMR (MJ/d) = $0{\cdot}0410W + 2{\cdot}610$,

where W is body weight (kg).

Measurement of energy intake

Metabolizable EI was measured for a 2 d period in twelve of the patients and a 3 d period in the other eight, using a weighed dietary record. Timing of measurements was the same as for RMR: within 48 h of admission, 14 d post-admission (±48 h), and 28 d post-admission for those patients still in hospital at that time. In all cases the weighed dietary record was carried out within 2 d of each RMR measurement.

On days of weighed dietary intake assessments, all foods and fluids consumed were weighed and recorded by a trained observer (K.K.-G.). Food at the hospital is cooked in a central kitchen off-site and is transported to the hospital in heated trolleys. All food is served from trolleys located in central ward corridors and transferred to four- to six-bedded units leading off each corridor. Patients completed menu cards in order to select food choices for the following day, which consisted of three cooked meals (breakfast, lunch, dinner) plus mid-morning and mid-afternoon hot drinks, and evening snack (toast). All food items served from trolleys were weighed at the time of serving and the observer remained in the corridor (out of sight of the patients) during the meals. Nursing or auxiliary staff returned the plates (with or without leftovers) for re-weighing. Using this procedure food energy 'served' and 'consumed' were quantified separately. Consumption of food and fluid at mid-morning, mid-afternoon and snacks was recorded by nursing or auxiliary staff and the trained observer on a data-form kept at the bottom of each patient's bed. 'Standard' portions of full, half and quarter cups and toast were determined in a pilot study by weighing ten to twenty portions of each item (K. Klipstein-Grobusch, unpublished results) and were used to quantify nutrient intake outside main meal times. All recording days were week-days.

Consumption of food items brought in by relatives was limited and was quantified by interview with patients and/or recorded by nursing and auxiliary staff. All food intakes were converted to nutrient intakes using a computerized version of McCance and Widdowson's *The Composition of Foods*. Individual EI values for each day are presented together with mean EI for each individual. Five of the patients received a high-protein, high-energy diet while in hospital. This consisted of a standard diet supplemented with standard soup and dessert made using skimmed-milk powder. The composition of the supplement was determined by obtaining catering information, and the quantities added measured directly.

Design of assessment of EI was problematic for reasons similar to those given in relation to RMR above. The day-to-day variability in EI might have been expected to be limited based on evidence from the literature on other groups of elderly patients (e.g. Barnes & Hodkinson, 1988). However, the nature of any change in EI was difficult to predict for this group of patients, as was the duration of hospitalization (and indeed the outcome: patients are acutely and seriously ill and a proportion die in hospital). It was therefore decided to sample EI at approximately the same time that energy expenditure was sampled, using fortnightly assessments for the duration of up to 4 weeks. For the eight patients with three measurements of EI the mean coefficient of variation of EI was 25 (range 7–41)%. In eleven patients there was an apparent increase in EI during hospitalization, in six a decrease, and in three no discernible change. However, no clear pattern in temporal variation in EI was apparent (see Table 3). It was therefore considered justifiable to combine EI data for each patient for the purposes of determining the energy balance status of patients during the course of hospitalization.

Assessment of energy balance

Energy balance was calculated in two ways. First, by expressing observed mean EI as a ratio of measured mean RMR. The TEE (or energy requirement) of each patient is greater than RMR because of the energy cost of physical activity and the thermic effect of food. In practice, since most patients were essentially confined to bed or chair for most of their period in hospital the energy expended on physical activity must have been limited. In a similarly inactive group of (long-stay) geriatric patients the mean TEE:BMR ratio was 1·30 (TEE determined by doubly labelled water; Reilly *et al.* 1992). For this reason TEE was estimated as 1·3 × measured BMR for the purposes of determining the energy balance of

Table 1. *Characteristics of patients on admission*

Subject	Age (years)	Main diagnosis	MMT score*	Weight (kg)	BMI† (kg/m^2)	% Body fat‡
Males						
1	73	Abd	10	62·0	21·8	22·0
2	77	CVS	10	40·7	14·6	9·2
3	79	CVS	10	71·2	23·8	22·9
4	82	CNS	6	75·9	24·8	26·9
5	85	Other	N/A	33·1	13·6	7·3
6	85	Bone	8	59·0	21·6	14·3
7	85	Bone	8	80·6	26·7	26·9
8	89	Bone	9	50·5	18·2	18·0
Mean	82		9	59·1	20·6	18·4
SD	5		1	16·9	4·8	7·6
Females						
9	77	Mal	10	49·8	20·9	28·4
10	78	Other	8	46·5	19·6	—
11	78	CVS	10	51·7	22·3	34·7
12	79	GUS	4	40·8	17·6	25·1
13	80	Abd	9	44·7	17·4	24·1
14	82	CNS	9	51·6	21·8	32·4
15	82	CNS	5	31·4	14·5	13·9
16	85	CNS	10	68·7	32·7	36·4
17	86	Mal	10	63·5	26·8	38·6
18	92	CNS	8	52·0	22·2	31·9
19	92	Resp	9	46·0	21·1	29·9
20	96	CNS	N/A	57·0	26·1	33·7
Mean	84		8	50·3	21·9	29·9
SD	6		2	9·9	4·9	6·9

MMT, mini mental test; BMI, body mass index; Abd, abdominal pain; CVS, cardiovascular disease; CNS, central nervous system; Bone, bone disease; Resp. respiratory disease; Mal, malignancy; GUS, genito-urinary system; N/A, not available.

* Not applicable for two patients due to expressive dysphasia.

† Stature predicted from knee height.

‡ Body fatness estimated from sum of four skinfolds.

each patient. While this approach will entail some error in individual patients this error is unlikely to be great for the present purposes given the limited engagement in physical activity of the patients, and is consistent with the factorial approach to estimating the TEE:BMR ratio in inactive hospital inpatients outlined recently (Department of Health, 1992). Energy balance was also quantified as the EI:estimated TEE ratio, and by calculating the difference between measured EI and estimated TEE.

Statistical analysis

Between-group comparisons were made by two-sample *t* test. A one-sample *t* test was used to test the hypothesis that the predicted BMR:mean measured RMR ratio was significantly different from unity.

RESULTS

Characteristics of patients on admission

Age, clinical details, and anthropometric data on admission are presented in Table 1. Most patients (thirteen of twenty) were independent in activities of daily living and fourteen of

Table 2. *Changes in anthropometric variables of acutely ill elderly patients during hospitalization**

Subject	Duration of stay in hospital (d)	Change in			
		Weight (kg)	Fatness (% body wt)	MAMC (mm)	BMI (kg/m²)
1	20	−0·8	−1·6	−0·4	−1·0
2	15	0·0	0·0	0·0	0·0
3	20	−0·7	−0·8	0·8	−0·2
4	33	0·0	−0·5	−1·0	0·0
5	> 42	0·1	−2·6	−0·1	0·0
6	> 42	−4·8	0·2	−0·9	−1·7
7	10	1·4	−0·2	−0·7	0·5
8	> 42	−0·7	0·1	−0·4	−0·3
9	15	−1·2	−0·9	0·9	−0·5
10	20	0·0	0·0	−0·1	0·0
11	12	1·1	−0·2	−0·8	0·5
12	29	1·2	0·1	−1·7	0·5
13	17	0·3	0·4	−0·6	0·1
14	> 42	4·0	−0·5	0·5	1·7
15	39	2·5	1·4	−0·8	1·6
16	15	0·9	0·9	−2·3	0·4
17	> 42	−4·3	−2·4	−0·4	−1·8
18	> 42	0·9	−0·6	−0·1	0·4
19	34	−2·7	−1·5	0·8	−1·2
20	18	−1·4	−0·2	−1·0	−0·6
Mean		−0·2	−0·4	−0·4	−0·1
SD		2·0	1·0	0·8	0·9
95% Confidence interval		−1·2 to 0·7	−0·9 to 0	−0·8 to 0	−0·5 to 0·3
Paired *t* test		*P* = 0·66	*P* = 0·06	*P* = 0·04	*P* = 0·70
		NS	NS	Significant	NS

MAMC, mid-upper arm muscle circumference; BMI, body mass index; NS, not significant.

* Anthropometric changes were assessed over the course of 6 weeks hospitalization (mean duration of hospital stay 23 (range 10–46) d). For details of measurement procedures, see pp. 324–327.

twenty could feed independently. Nutritional status was generally poor, and this is discussed in detail in a separate communication.

Changes in anthropometric variables during hospitalization

Group changes in body weight were relatively minor during hospitalization (mean duration of stay 23 d; range 10–46 d; Table 2). A small and statistically significant decline in arm muscle circumference was observed (Table 2), with small declines in the other indices, including percentage body fat, which were not statistically significant (Table 2).

Resting metabolic rate

RMR averaged 5·1 (SD 0·8) MJ/d in the men and 4·5 (SD 0·9) MJ/d in the women (Table 3). Individual daily RMR values and mean RMR for each individual are presented in Tables 3 and 4. There was no evidence of higher RMR (kJ/kg) in septic (*n* 10) *v*. non-septic (*n* 10) patients (*t* test, $P > 0·05$).

Predicted BMR averaged 5·4 (SD 0·6) MJ/d for the men and 4·7 (SD 0·4) MJ/d for the women (Table 3). Predicted BMR exceeded measured RMR in twelve of nineteen patients, and though there was a suggestion (Table 4), particularly in the older patients (Table 4), that predicted BMR was biased to overestimation of RMR, the overall measured

Table 3. *Measured resting metabolic rate (RMR) and energy intake (EI) in elderly patients during hospitalization**

Subject	Measured RMR (MJ/d) Occasion			Measured EI (MJ/d) Occasion		
	1	2	3	1	2	3
Males						
1	5·4	5·7	5·0	3·9	3·0	—
2	5·0	5·3	—	4·9	6·3	—
3	5·2	5·9	—	4·1	3·8	—
4	5·9	6·3	—	4·9	4·8	—
5	3·7	3·6	3·1	4·4	5·0	6·3
6	—	—	—	5·8	2·8	6·2
7	5·3	5·4	—	9·4	9·6	—
8	4·7	4·6	—	3·4	4·6	—
Mean	5·0	5·3	4·1	5·1	5·0	6·2
SD	0·7	0·9	—	1·9	2·2	—
Females						
9	5·0	5·0	—	3·2	4·3	—
10	5·8	5·7	—	4·6	6·6	—
11	5·5	5·8	—	4·1	4·6	—
12	5·7	—	5·1	3·2	7·1	5·5
13	3·9	4·4	—	6·9	6·4	—
14	4·8	4·5	3·6	4·9	6·1	7·0
15	3·2	3·0	3·3	4·0	2·6	3·0
16	5·2	5·1	—	3·7	4·3	—
17	4·3	4·2	4·0	4·1	4·4	4·7
18	3·4	3·6	3·3	4·8	1·9	4·1
19	4·3	4·0	3·4	3·3	5·0	3·3
20	4·1	3·7	—	3·9	2·8	—
Mean	4·6	4·5	3·9	4·2	4·6	4·6
SD	0·9	0·7	1·0	1·7	1·5	—

* RMR was measured using ventilated-hood indirect calorimetry; EI was measured using a weighed dietary record. Measurement took place fortnightly for 4 weeks, or until hospital discharge or death: occasion 1 within 48 h of admission, occasion 2 at 14 d (±48 h) and occasion 3 at 28 d (±24 h). For details, see pp. 325–327.

RMR:predicted BMR ratio was 0·954 (SD 0·16 *n* 19), which was not significantly different from unity (*t* 1·2, *P* = 0·23; one-sample *t* test).

Estimated Total Energy Expenditure

TEE, estimated as 1·3 × measured RMR (1·3 × predicted BMR for subject number 6), averaged 6·6 (SD 1·1) MJ/d for the men and 5·8 (SD 1·2) MJ/d for the women (Table 3).

Energy intake

Mean daily EI was 4·8 (SD 1·5) MJ for both sexes combined; 5·2 (SD 1·9) MJ for males and 4·5 (SD 1·1) MJ for females (Table 3). Individual daily absolute EI and mean individual EI are presented in Tables 3 and 4.

Mean energy provided to each patient was 8·2 (SD 1·9) MJ/d in men and 6·6 (SD 1·0) MJ/d in women (Table 4). The difference between mean daily energy provided and mean daily energy consumed for each individual (plate waste) ranged from 0·1 to 5·2 MJ/d.

Table 4. *Energy balance characteristics of acutely ill elderly patients during hospitalization**

Subject	Measured BMR (MJ/d)	Predicted BMR (MJ/d)	Estimated TEE (MJ/d)	Measured BMR (kJ/kg per d)	Mean EI (MJ/d)	EI−TEE (MJ/d)	EI (kJ/kg per d)	Energy provided (MJ/d)	EI/ measured BMR
Males									
1	5·3	5·2	6·9	110	3·5	−3·4	56	5·2	0·7
2	5·1	4·9	6·7	138	5·6	−1·1	137	8·0	1·1
3	5·6	5·9	7·2	101	4·0	−3·2	55	9·2	0·7
4	6·1	6·0	7·9	110	4·9	−3·0	64	8·2	0·8
5	3·5	4·6	4·5	113	5·2	+0·7	158	9·4	1·5
6	—	5·5	—	—	4·9	—	83	7·7	—
7	5·4	6·3	7·0	106	9·5	+2·5	118	11·5	1·7
8	4·6	5·2	5·9	126	4·0	−1·9	79	6·7	0·9
Mean	5·1	5·4	6·6	115	5·2	−1·3	94	8·2	1·0
SD	0·8	0·6	1·1	13	1·9	2·2	39	1·9	0·4
Females									
9	5·0	4·7	6·5	140	3·8	−2·7	75	6·3	0·8
10	5·8	4·5	7·5	122	5·6	−1·9	121	8·9	1·0
11	5·6	4·7	7·4	168	4·4	−3·0	64	5·4	0·8
12	5·4	4·3	7·0	175	5·3	−1·7	130	7·4	1·0
13	4·1	4·4	5·4	122	6·7	+1·3	149	6·8	1·6
14	4·3	4·7	5·6	123	6·0	+0·4	117	6·6	1·4
15	3·2	3·9	4·0	117	3·3	−0·7	106	6·7	1·0
16	5·2	5·4	6·7	118	4·0	−2·7	58	6·6	0·8
17	4·2	5·2	5·5	108	4·4	−1·1	69	5·5	1·0
18	3·4	4·7	4·5	97	3·6	−0·9	69	7·5	1·1
19	3·9	4·5	5·0	120	3·9	−1·1	85	5·3	1·0
20	3·9	5·0	5·0	103	3·3	−1·7	59	6·4	0·8
Mean	4·5	4·7	5·8	126	4·5	−1·3	92	6·6	1·0
SD	0·9	0·4	1·2	24	1·1	1·3	31	1·0	0·2

BMR, basal metabolic rate; TEE, total energy expenditure; EI, energy intake.
* For details of measurement procedures, see pp. 325–328.

Energy balance

The EI : RMR ratio ranged from 0·7 to 1·8 (Table 4), median 1·0 (both sexes combined). In eight of the nineteen patients the EI : RMR ratio was < 1·0; in fifteen of the nineteen the EI : RMR ratio was < 1·3. Estimated TEE therefore exceeded measured EI (Table 4) in fifteen of the nineteen patients. The difference between measured EI and estimated TEE (negative energy balance) averaged 1·3 (SD 2·2; range −3·4 to +2·5) MJ/d in men and 1·3 (SD 1·3; range −2·7 to +0·4) MJ/d in women.

DISCUSSION

The subjects in the present study comprised a sample of acutely sick elderly patients in which nutritional status gave cause for concern. That is, undernutrition would seem to be a problem in this patient group, as in other groups of elderly patients studied more extensively (Morgan *et al.* 1986; Prentice *et al.* 1989; Sutherland & Wooton, 1993). The present study focused on obtaining evidence which might predict the course of changes in nutritional status in these patients during hospitalization in the absence of frank changes (e.g. weight changes) which take long periods to develop. The related question of the adequacy of food/nutritional provision was also addressed. The evidence obtained from this relatively small-scale study suggests that negative energy balance is common in this patient group during hospitalization, as in other groups of elderly in-patients (Prentice *et al.* 1989; Sutherland & Wooton, 1993). The observed EI were generally low (with a few exceptions; Table 3), and were similar to rates of EI reported in different elderly patient groups (Thomas *et al.* 1988; Sutherland & Wooton, 1993). Clear trends in EI or expenditure were not apparent during hospitalization and identifying such trends would require a larger sample of subjects with more intensive measurements of intake and expenditure.

The actual measured changes in body weight during hospitalization (Table 2) were relatively small, but this is not unexpected given the relatively short-term nature of hospitalization, the period of time required for such changes to become apparent, and the possible confounding effects of small daily variations in body weight. There was a significant decline in MAMC (Table 2) and a decline in body fatness during hospitalization. The magnitude of the changes observed was broadly consistent with the moderate estimated negative energy balance (mean $-1{\cdot}3$ MJ/d) given the imprecision of the methods. Furthermore, in fourteen of nineteen patients the direction of estimated energy balance correctly predicted the direction of weight change. In the other five patients weight was gained despite apparent negative energy balance. This may have been due to confounding of body-weight change (most of these patients showed small changes in weight), or imprecision of the energy balance assessments. Alternatively, EI may have been in excess of that observed during the recording period or, more likely, outside the recording period. Since EI and RMR assessments were carried out for up to 4 weeks but anthropometric changes were assessed for the duration of hospitalization (up to 46 d), some discrepancy between energy balance and weight change data is perhaps not surprising. Individual variability in energy intake and expenditure, and anthropometric changes, was high which is also not surprising in view of the diverse nature of the patient group. However, the evidence presented here suggests conclusively that negative energy balance was the norm for the group, and this is supported by the anthropometric changes observed (Table 2).

Low EI, even if energy expenditure is met, give cause for concern because they usually represent a marker of low vitamin and mineral intake (Department of Health, 1992; Lowik *et al.* 1993). At low EI it becomes extremely difficult to meet requirements for intake of vitamins and minerals given the relatively low nutrient densities in the diet of many institutions, and this almost certainly contributes to the high prevalence of poor status or deficiency of vitamins and minerals in hospitalized elderly patients (Morgan *et al.* 1986; Lehmann, 1989). Intakes of various vitamins were indeed low (particularly vitamin C) in the present study, but given the imprecision of the dietary record for the assessment of micronutrient intake these results are not presented here. The energy balance results therefore suggest that weight loss is expected under these conditions, and imply that these patients are also at risk of deterioration in vitamin and mineral status during hospitalization.

The sample of patients was characterized by better cognitive function and mobility than is typical of acutely sick elderly patients due to the inclusion and exclusion criteria adopted, and we speculate that deterioration in nutritional status is perhaps an even greater problem in more typical acutely sick elderly patients. There is a paucity of information in this area and the result needs to be confirmed by larger-scale studies. The practical significance of the results obtained may also have been underestimated because of the relatively short duration of the study. Patients remained in hospital for < 4 weeks in most cases and were not followed up after discharge, but gradual deterioration in nutritional status, or episodic deterioration associated with illness, would seem likely in a proportion of the patients. The aetiology of undernutrition in elderly patients is poorly described yet is of considerable importance if successful nutritional intervention strategies are to be designed (Williams *et al.* 1989). A high proportion of patients reported substantial weight loss in the months or years before admission, but this was impossible to quantify or verify.

In general terms the quantity of food (energy) provided to the patients was sufficient to meet TEE (Table 4), in contrast to findings in some other elderly patient populations (e.g. Thomas *et al.* 1988; Prentice *et al.* 1989; Sutherland & Wooton, 1993). Low EI values were therefore presumably associated with factors other than inadequate food provision, at least in terms of food quantity. This may provide evidence as to which strategies might be adopted in acutely sick elderly patients in order to reverse undernutrition and/or prevent deterioration in nutritional status (Williams *et al.* 1989; Larsson *et al.* 1990). It would seem that efforts should be concentrated on increasing appetite or palatability of food (or providing some form of supplementation) during acute illness, treating underlying feeding or swallowing difficulty, or addressing the problem of nutritional repletion after the acute episode. In order to address problems associated with low vitamin and mineral intake, dietary approaches aimed at increasing the nutrient density of the diet might be considered.

In order to design nutritional intervention in elderly subjects the assessment of energy requirements can be considered a starting point. One simple approach which might be used clinically is the estimation of energy requirements using predictive equations. Cross-validation of such equations in younger adults has revealed both substantial biases and random errors (Clark & Hoffer, 1991), and a detailed discussion of this topic is inappropriate here. Even less information on the cross-validation of predictive equations in the healthy elderly is available, and we know of no relevant data for the hospitalized elderly. The present study found no clear evidence of systematic error in application of the Department of Health (1992) predictive equations to these patients, though the range of individual errors was large, as expected. Further research on larger samples of patients is necessary to identify biases and determine whether they are of practical significance.

In conclusion, the present study suggests that negative energy balance is common in acutely sick elderly patients admitted from the community (even when the quantity of food provided is adequate) and for the first time provides information on the magnitude of the energy deficit which might be expected. This patient group, in which undernutrition appears to be quite common on admission to hospital, is therefore at risk of progressive or episodic deterioration in nutritional status during hospitalization and, possibly, following discharge. The clinical effects of poor nutritional status are serious and well described (Lehmann, 1989; Chandra, 1990; Kings Fund Centre, 1992) and further research on the identification, treatment and aetiology of undernutrition in the acutely sick elderly is indicated.

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