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Original Article

Energy expenditure and nutritional adequacy of rehabilitation paraplegics with asymptomatic bacteriuria and pressure sores

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Objective: To measure resting energy expenditure (REE) in a group of people with postacute paraplegia, quantify the impact of asymptomatic bacteriuria and pressure sore(s) on patients' metabolic rate, and estimate the adequacy of patients' nutritional intakes to preserve patients' protein levels.
Material and methods: Ten males with post-acute paraplegia aged 42.1 $\pm$ 18.7 years. We evaluated: height, body mass index (BMI), resting energy expenditure (REE), total daily calorie requirement ($\dot{E}$), 24-h urine creatinine excretion (Cru), creatinine index (CI), and nitrogen balance (NB).
Results: Subjects with paraplegia showed high erythrocyte sedimentation rates. As a group, they had normal resting calorie consumption when REE was normalized for unit of urine creatinine (REE/Cru), it was higher in patients than in controls. Six of the 10 patients had a low calorie intake: of these only three had a negative nitrogen balance.
Conclusion: In conclusion, the resting energy expenditure of the subjects with significant bacteriuria and pressure sore(s) of 23.7 kcal/kg/day suggests that a large portion of patients may have an inadequate calorie protein intake to preserve their nutritional status. The clinical significance of this study is that 28.5 kcal/kg/day may be the lower calorie threshold to meet the metabolic demands of people with apyretic paraplegia with bacteriuria and pressure sore(s).
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Keywords: spinal cord injury; asymptomatic bacteriuria; pressure sore(s); inadequate calorie intake

Introduction

Urinary tract infections and pressure sore(s) often represent important secondary medical complications in patients with traumatic paraplegia over time. In our rehabilitation setting the prevalence of urinary infections is 32.9%, and of pressure sore(s) 12.8%.

While the influence of any clinically overt infection is to increase patients' metabolic rate, so far it has not been investigated whether significant bacteriuria ($>10^5$ colonies per milliliter of urine) associated with pressure sore(s) has any impact on resting energy expenditure (REE) of people with apyretic paraplegia. For clinical purposes this is not a trivial problem, because if significant bacteriuria and pressure sore(s) increased REE, it should be mandatory to monitor over time the adequacy of patients' nutritional intake to avoid further trophic and nutritional wasting[1,2] induced by spinal injury, reduction in host immunocompetence[3] and increase in skin breakdown:[4] all factors that contribute to the resolution of infective diseases and skin wound healing.

Knowledge of REE is a key to calculating patients' total daily energy requirements ($\dot{E}$) and thus to evaluating whether patients' calorie intakes are sufficient for $\dot{E}$.

We therefore aimed to measure REE in a group of people with postacute paraplegia, quantify the impact of asymptomatic bacteriuria and pressure sore(s) on patients' metabolic rate (stress factor) and estimate the adequacy of patients' nutritional intakes to preserve their present nutritional status.

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Methods

Subjects
Ten males with post-acute paraplegia ($\geqslant 2$ months after acute trauma from car or motorbike accidents) were enrolled for the study at admission to our Institute. Their age was 42.1 ± 18.7 years (range 18–72). All patients had a complete lesion (class A in the ASIA impairment Scale), with indwelling urinary catheters and were complicated both with significant bacteriuria, ($>10^5$ colonies per milliliter of urine), and pressure sore(s). At the time of the study, all patients were apyretic, could eat independently and were undergoing physical therapy consisting of 2 h a day of range of motion activities and occupational therapy. Table 1 reports clinical characteristics and some biohumoral parameters of the study population.

Patients were not asked written consent because nutritional evaluation is a routine practice in our Institute. However, they were informed verbally about the procedures and the usefulness of nutritional assessment.

Controls
Regarding the resting energy expenditure and creatinine excretion, the patients were compared to five healthy sedentary subjects (three women, two men) with both similar body mass index and loss of percentage of body weight occurring over the last 3 months as a result of voluntary uncontrolled dieting (control group). Control subjects were submitted to the same experimental protocol used for patients.

Anthropometry
In all patients, height was estimated by knee height.[5] Weight was measured by a mechanical weight lift (Partner, PABISH) and recorded as a percentage of usual body weight (% UBW).

Body mass index (BMI) was calculated as:

$$\mathrm{BMI} = \mathrm{Wt(kg)}/\mathrm{Ht}^2\ (\mathrm{m}^2) \qquad (1)$$

Resting energy expenditure (REE)
Indirect calorimetry with a horizon metabolic measurement chart (Beckman Instruments, Anaheim, CA, USA) was used to measure patients' oxygen consumption and carbon dioxide production from which to calculate REE.

The measures were performed at 09:00 am, 12 to 14 h after overnight fasting. A canopy was used to collect the expired air. Oxygen consumption and carbon dioxide production were measured at 1-min intervals for 60-min and the mean of the last 5 min was calculated. REE were calculated from gas analyses according to the Weir equation.[6] $\mathrm{REE} = [3.9\ (\dot{V}O_2) + 1.1\ (\dot{V}CO_2) \times 1.44$ kcal/day]. REE was then compared to the predicted value from the Harris-Benedict equation (H-B)[7] for healthy normal males: $\text{H-B} = 5.0033 \times H + 13.7516 \times W + 66.473 - 6.755 \times A$ (age in years) kcal/day.

Normal REE value is usually set at 90–110% of the resting energy expenditure predicted by H-B.

Patients' total daily calorie requirement ($\dot{E}$) was calculated as REE + 20% where 20% is a factor accounting for the daily motor activity of patients.[8]

Table 1 Clinical characteristics and biohumoral parameters of study population

Levels of traumatic lesion	D^1–D^6	3/10 pts
	D^7–D^{10}	2/10 pts
	D^{10}–L^1	5/10 pts
Sides of pressure sores	Ischial sacral	6 pts
	Heel	4 pts
Laboratory results		
White blood count ($\times 10^3$/mm^3)	9.03 ± 3.5 (4.7–12.3)	
Erythrocyte sedimentation rate (mm/h)	52 ± 22.6 (12–86)	
Hemoglobin concentration (g/dl)	10.9 ± 1.2 (7.8–12)	
Serum albumin concentration (g/dl)	3.56 ± 0.5 (2.6–4.4)	

Values are expressed as mean ± standard deviation. Range in brackets

Biochemical analysis
Twenty-four-hour urine creatinine excretion (Cru) was determined with patients on a 3 day meat-free diet.[9] Cru was then compared to the predicted value for males of the same age and ideal height to obtain the creatinine index.[10] To evaluate muscle protein mass[9,10] a creatinine index lower than 90% of that predicted was considered significant for muscle protein loss.

Nutritional analysis
Calculations of calorie and macronutrient intakes were made by recording the type and weight of the patient's cooked and uncooked food for 3 days, not concurrent to those when for creatinine excretion was determined.[11] The findings were converted into the raw equivalent when necessary using tables.[12]

Nutritional analysis using a computed system designed by our group allowed us to calculate the actual calorie and macronutrient intake. In all patients, calorie intake (kcal-I) was expressed either in absolute values or as a percentage of total daily calorie requirements ($\dot{E}$).

On the last day of food recording, nitrogen output (NU, g/24 h) was assessed from 24-h urine excretion samples. Nitrogen balance (NB), was calculated according to the following equation:

$$\mathrm{NB(g/day)} = \mathrm{NI} \quad \mathrm{NU} + 2\ \mathrm{g} \qquad (2)$$

Where nitrogen intake (NI, g/day) is obtained from protein intake divided by 6.25, and 2 g is a constant of the number of grams of nitrogen to compensate for skin and fecal losses.[10] A negative NB indicates an excess of endogenous protein breakdown, while a positive NB means preservation of tissues or generation of new ones.

Criterion of inadequate calorie intake
Inadequacy of calorie intake to preserve current nutritional status of patients was established only when a low calorie intake (kcal-I < 120% $\dot{E}$) corresponded with a negative nitrogen balance.

Statistical analysis
Values are expressed as mean ± standard deviation ($\bar{x} \pm$ sd). The unpaired *t*-test was used to compare anthropometric, energy expenditure, and biochemical parameters between patients and controls. Statistical significance was set at $P < 0.05$.

Results

As a group, the subjects with paraplegia showed high erythrocyte sedimentation rates so their bacteriurias were considered as urinary tract infections and consequently antibiotic therapy was started (Amikacine i.v. 10/day for 8 days). Table 2 reports anthropometry, resting energy expenditure and urine creatinine excretion in subjects and controls.

Over 2 months, our group of postacute paraplegics with significant bacteriuria + pressure sore(s) lost 9.95 ± 4.4 kg, ie 15.6 ± 7.2% of their usual body weight, statistically similar to the 11 ± 5.3% observed in controls.

As a group, subjects with paraplegia had normal resting calorie consumption, because REE was within the normal range of values predicted by the HB equation (96 ± 13.7% HB) but higher than in controls ($P < 0.01$). In absolute values, the mean REE was tendentiously higher in subjects than in controls (23.7 ± 4.5 *vs* 19.6 ± 2.2 kcal/kg; $P < 0.07$). Total daily energy need ($\dot{E}$) in subjects with paraplegia was calculated to be 28.5 ± 5.4 kcal/kg/day.

As expected[1,2] patients had lower muscle mass than controls, even though both loss of body weight and BMI were similar between the two groups. Indeed, the creatinine index (CI) was found to be 40.9 ± 7.9% in patients and 68.7 ± 14.8% in controls ($P < 0.001$). Our results also showed that REE normalized for unit of urine creatinine (REE/Cru) was higher in patients than in controls ($P < 0.001$). Table 3 reports calorie, macronutrient, nitrogen intakes (NI), 24-h urinary nitrogen excretion (NU), and nitrogen balance (NB) of the patients.

Table 3 Paraplegic calorie and macronutrient intakes, urinary nitrogen excretion and nitrogen balance

Nutritional intakes	
Calorie	
kcal/day	755 ± 344 (1264–2372)
kcal/kg	27.6 ± 5.9 (16.8–34.7)
% $\dot{E}$	109 ± 18 (82.3–132.4)
Macronutrients	
Carbohydrates	
g/kg	3.44 ± 0.8 (1.76–4.4)
% calories	49.7 ± 3.2 (43.5–54)
Proteins	
g/kg	1.09 ± 0.4 (0.65–1.54)
% calories	16 ± 3 (10.8–20)
Nitrogen (as protein: 6.25)	
g/24 h	11.4 ± 2.9 (7–15.8)
Lipids	
g/kg	0.99 ± 0.21 (0.58–1.3)
% calories	34 ± 4 (27–40)
Urinary nitrogen excretion g/24 h	6.9 ± 3.7 (2.72–13.9)
Nitrogen balance g/24 h	−0.28 ± 5.7 (−10.2–8.3)

Table 2 Anthropometry, resting energy expenditure and urine creatinine excretion in paraplegics and controls of the study

	Paraplegics	*Control*	P
Age (yrs)	42 ± 18.7 (18–72)	27.6 ± 7.7 (22–41)	ns
Actual body weight			
kg	64.8 ± 11.3 (47–80)	54.3 ± 4.9 (49–60)	ns
%UBW	84.4 ± 7.2 (71–93.7)	88.8 ± 8 (83–94)	ns
Weight loss			
kg	9.9 ± 4.4 (5–20)	5.9 ± 2.3 (3.5–9.2)	ns
%UBW	15.5 ± 7 (7–29.4)	11.2 ± 4.8 (6–17)	ns
BMI (kg/m^2)	21.1 ± 3.2 (17.3–27.6)	19.5 ± 1.9 (18–21.5)	ns
REE			
kcal/24 h	1469 ± 217 (1167–1888)	1059 ± 45.5 (989–1105)	< 0.001
kcal/kg	23.7 ± 4.5 (18.2–32.9)	19.6 ± 2.3 (16–21.7)	ns
%HB	96 ± 13.7 (79–119)	77 ± 6.7 (69–86)	< 0.001
Cru (mg/24 h)	602 ± 177 (426–1134)	821 ± 206 (560–1120)	< 0.05
CI (%)	40.9 ± 7.9 (32–60)	68.7 ± 14.8 (47.7–88)	< 0.001
REE/Cru (kcal/mg)	2.56 ± 0.5 (1.7–3.4)	1.35 ± 0.12 (1.22–1.65)	< 0.001

Values are mean ± standard deviation. Ranges in brackets. UBW: usual body weight; BMI: body mass index; REE: resting energy expenditure; Cru: 24-h urine creatinine excretion; CI: creatinine index

Patients' calorie intake averaged 1755 ± 344 kcal/day (= 27.6 ± 5.9 kcal/kg/day).

Six of the 10 patients (60%) had low calorie intake, kcal-I being 97 ± 15% total daily energy requirements ($\dot{E}$).

In three of these patients a negative nitrogen balance was also found. Consequently an inadequate calorie intake to preserve actual nutritional status was diagnosed in 30% of the patients.

Two of the above three patients also had a reduced protein intake (< 1 g/kg/day) while the third patient had a low calorie intake but tendentially high protein assumption (1.48 g/kg/day).

Discussion

Apyretic patients with post-acute paraplegia complicated with significant bacteriuria and pressure sore(s) were found to have average resting energy expenditure of 23.7 kcal/kg/day, significantly higher than in controls having a similar percentage of body weight loss and body mass index but higher energy-consuming muscle mass. This means that energy consumption in paraplegics of the study is in excess of what would be expected from patients' current nutritional status. There are two possible explanations for the excess of energy expenditure found in subjects with postacute paraplegia. First, calorie consumption per unit of muscle mass (REE/Cru) was significantly higher in subjects than in controls, suggesting an increase in oxidative metabolism within muscle cells. Second, as a group, the subjects had lost their metabolic adaptive response to drop in weight[13] and to muscle atrophy .[14] Indeed, as a percentage of the predicted value, REE was normal (96% HB), and not lower than 90% of HB as one would expect for body adaptive response and as was actually observed in controls (77% HB). It is likely that important tissue inflammatory responses to bacteriuria and pressure sore(s) are responsible for both increased muscle metabolism and reduced metabolic adaptive response to body wasting. Our results indicate that metabolic stress factor induced by bacteriuria and pressure sore(s) is around 20.9% REE in postacute clinically apyretic paraplegics. This value is similar to that estimated (20%) by Kaufman for trauma disease or infection in acute spine injury.[15]

Total daily energy requirement ($\dot{E}$) in our subjects was 28.5 kcal/kg/day, close to that calculated by Cox (27.9 kcal/kg/day) in non-complicated people with paraplegia, evaluated at the same time from injury and after the same duration of physical therapy.[16] It seems, therefore, that the presence of bacteriuria and pressure sore(s) has very little impact on the metabolic rate of these subjects. However, Cox's patients and those of the present study are not comparable, as body wasting due to injury was less pronounced in Cox's patients than in ours; average weight loss being 5.3 kg in Cox's patients and 9.9 kg in ours. If our patients had not had bacteriuria and pressure sore(s), their REEs would likely have been lower than those observed in Cox's study and would have approached the REEs found in controls. Moreover, correct comparison between the REEs in the two populations would require careful standardization of the factors influencing REE, such as degree and level of injury, nutritional support in acute phase of spinal injury, amount of daily physical activity and medication.

This study shows that 50% of the self-feeding subjects with paraplegia and significant bacteriuria and pressure sore(s) had low calorie intakes but in 30% of all subjects low calorie intake was associated with negative nitrogen balance, meaning an inadequate calorie intake to preserve their current nutritional status. The average calorie intake of paraplegics in this investigation was 1755 kcal/day, 21% higher than that estimated by Laven[17] by daily observation of patients' meal tray at the same time after injury. It is possible that the low calorie intake found in half of the patients of the study may be due to reduced appetite and/or to the early sensation of satiety frequently observed in spinal cord injury patients,[17] though a low preference for hospital catering can not be excluded.

It is likely that negative nitrogen balances observed in three of these patients were partly due to low protein intakes, partly to loss of proteins from pressure sore(s), that can amount to as much as 50 g/day.[17] The highest negative nitrogen balance (8.16 g/day) was found in a patient with tendentially high protein assumption (1.48 g/kg) and low calorie intake (103% $\dot{E}$), indicating high endogenous protein breakdown probably as a consequence of substantial protein loss from a vaste pressure sore(s) at the ischiatic sacral level.

In conclusion, this study suggests that resting energy expenditure of subjects with postacute apyretic paraplegia with significant bacteriuria and pressure sore(s) may be set at 23.7 kcal/kg/day and that a large proportion of patients may have an inadequate calorie protein intake to preserve their actual nutritional status. The clinical significance of this study is that 28.5 kcal/kg/day may be the lower calorie threshold to meet the metabolic demands of subjects with apyretic paraplegia with bacteriuria and pressure sore(s).

Limitations of the study

We are aware that nitrogen balance is not a reliable measure in case of extra urinary nitrogen loss as may occur in pressure sore(s). In this context, however we think that its determination is useful anyway because, if positive or in equilibrium, it indicates to the physician that the patients' nutritional intake is adequate to body needs, not withstanding medical complications; if negative, it may indicate the minimum extra amount of proteins (and/or calories) that should be supplied to the patient.

This study does not reveal the separate contribution of significant bacteraemia and pressure sore(s) to the observed extra energy expenditure in paraplegics. Future studies will be addressed to this issue.

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