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Resting Energy Expenditure and Body Composition in Bedridden Institutionalized Elderly Women With Advanced-Stage Pressure Sores

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Background. Our study investigated nutritional status, body composition, and resting energy expenditure (REE) in elderly patients with advanced-stage pressure sores (PS), in addition to researching any hypermetabolic condition and its relationship with PS size.

Methods. The study involved 52 institutionalized bedridden elderly women (aged 83.7 ± 6.3 years), divided into two groups: 23 with advanced-stage (stage 3 and 4) PS and 29 without PS. Albumin, prealbumin, and retinol-binding protein were measured in all patients, and fat-free mass (FFM) and fat mass (FM) were obtained by dual-energy x-ray absorptiometry (DEXA). REE was measured by indirect calorimetry and predicted with the Harris–Benedict formula. PS area and volume were also measured.

Results. The elderly women with and without PS were comparable in age, FFM, and FM. Mean albumin, prealbumin, and retinol-binding protein values were lower in cases with PS (1212.3 ± 236.7 vs 1085.5 ± 161.3 kcal/d; p < .05), even after adjusting for FFM or expressed per kilogram of body weight (25.8 ± 6.7 vs 21.1 ± 4.0 kcal/d/kg; p < .01). Hypermetabolism, i.e., a measured REE > 110% of the predicted REE, was seen in 74% of patients with PS and 38% of controls. The difference between measured and predicted REE (ΔREE) correlated with PS volume (r = 0.58; p < .01), but not with area.

Conclusion. Advanced-stage PS in elderly women are associated with a hypermetabolic state that is influenced by the volume of the PS.

Pressure sores (PS) are a significant problem for elderly people, particularly the disabled and bedridden (1). PS prolong hospital stays, interfere with quality of life, and raise morbidity and mortality rates (1–3).

Nutritional assessment is important in preventing PS (4,5) and identifying patients at risk (6). Among risk factors for PS, malnutrition is potentially reversible, and its early identification and treatment may affect PS onset and progression. Many studies demonstrate the relationship between malnutrition and risk of PS (3,5,7), and PS have healed better in patients given calorie supplements or specific macronutrients and/or micronutrients (8,9).

Among factors causing malnutrition in elderly people with PS, an increased resting energy expenditure (REE) may be important, as PS are like burns, for which a high calorie requirement has been clearly documented (10).

Among individuals suffering from PS, hypermetabolism has only been demonstrated in adult paraplegic patients (11–13). It is more difficult to study REE and hypermetabolism in elderly people with PS, however, due to numerous potential confounding factors: age-related reductions in lean body mass and muscle mass (14) and limited physical activity mean lower basal energy requirements (15). In contrast, associated infections and the wound healing process could increase energy expenditure, as in burn patients. Advanced-stage PS presumably increase REE in elderly persons too, because they demand considerable tissue repair.

A recent article investigating energy requirements in elderly patients with PS found them no greater than in patients without PS (16), but this important study considered patients with PS in different stages, and did not investigate body composition. Our study aimed to investigate nutritional status, body composition, and energy metabolism in bedridden elderly patients with advanced-stage PS, and to identify any hypermetabolic conditions and their relationship with PS size.

METHODS

Patients
This study, performed at the Long-Stay Division of Padua Geriatric Hospital, involved 52 bedridden females older than 65 years (83.7 ± 6.3 years), in long-term care, divided into two groups: 23 with PS in stages 3 or 4 according to the Shea classification (17) and 29 without PS. The average length of the patients’ stay was 39 ± 8 days. Only patients with perfectly clean PS, with no smells or exudates after toileting of necrotic tissue and a period of regular medication were considered.

For all patients, exclusion criteria were a body mass index (BMI) > 30; fluid retention or dehydration; fever; acute disease; liver, heart, or kidney failure; endocrine disorders; anemia (Hct < 25%); cancer; rheumatic and immunological...
diseases; and use of some drugs interfering with resting metabolic rate (beta-blockers, theophylline, corticosteroids, hormones, benzodiazepines, and opioids). Leukocyte levels above $11.00 \times 10^3/\mu L$ (corresponding to the upper limit of the normal range at our laboratory) were considered a reason for exclusion. We also excluded 13 male patients (6 PS and 7 controls) from the data analysis because the size of the male sample was too small. These men were not considered together with the women to avoid any gender-related confounding factors (e.g., different body compositions and hormone patterns) influencing the REE (18). The study was designed in accordance with the Helsinki Declaration; patients or their relatives were fully informed about the nature and purpose of the study, and gave their informed consent.

Protocol

The following measurements were taken for all patients on the same morning:

Biochemical analysis.—Blood samples were drawn in the morning after a 12-hour overnight fast. Routine biochemical analyses of albumin, prealbumin, and retinol-binding protein (RBP) were performed to assess clinical and nutritional conditions; erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), fibrinogen, and leukocytes were evaluated to investigate inflammatory state.

Functional status was evaluated according to the Activity of Daily Living index (ADL) (19), to test level of independence in bathing, dressing, toileting, transferring, continence, and feeding, using the Katz Index, scored from 0 (total independence) to 6 (total dependence).

PS risk was estimated using the Braden Scale (20): The six subscales reflect critical pressure determinants and factors influencing the skin’s and supporting structures’ pressure tolerance. Subscales were rated from 1 (least favorable) to 4 (most favorable) for a maximum total of 23. The risk of developing PS was set at 16 points or less.

Cognitive performance was assessed with the 10-item Short Portable Mental Status Questionnaire (SPMSQ). Cognitive performance was scored as the number of errors, 10 being the maximum, correcting the raw score for education according to Pfeiffer (21).

Comorbidity was assessed by means of the Cumulative Illness Rating Scale (CIRS). This scale identifies 14 items corresponding to different systems. Each system is scored as follows: 1 = none (no impairment to the specific organ/system), 2 = mild (impairment does not interfere with normal activity, treatment may or may not be required, and prognosis is excellent), 3 = moderate (impairment interferes with normal activity, treatment is needed, and prognosis is good), 4 = severe (impairment is disabling, treatment is urgently needed, and prognosis is guarded), or 5 = extremely severe (impairment is life-threatening, treatment is urgent or of no avail, and prognosis is not good). These items were used to calculate the Illness Severity Index (a summary score based on the average of all CIRS items) and the Comorbidity Index (a summary score counting the number of organs and/or systems with moderate or worse impairment) (22,23).

Daily food intake was measured by weighing all food consumed over 3 days and recording the weight of each plate to the nearest gram before and after meals with precision scales; the foods eaten were recorded in a diary. Total daily calorie and nutrient intake was calculated by the Geriatric Division’s dietician using the tables of the Italian Nutrition Institute (24).

PS area and volume measurement.—Each PS was flattened with a specific graduated film (Opsite: Smith & Nephew, U.K.), its area was calculated in centimeters, and its volume was measured by injecting physiological solution through the same film until it was full.

Anthropometry.—Body weight was measured to the nearest 0.1 kg and height to the nearest 0.1 cm, with patients wearing light clothing and no shoes. For patients whose height was difficult to measure or unreliable due to a bent back or leg anchylosis, their height was established from their knee-to-heel length according to Chumlea (25). BMI (weight [kg]/height² [m]) was also calculated.

Body composition.—Fat-free mass (FFM) and fat mass (FM) were obtained by dual-energy x-ray absorptiometry (DEXA) using fan-beam technology (Hologic QDR 4500 W; Waltham, MA) and Hologic software (release 8.21) for body composition evaluation. DEXA is highly reproducible in determining soft tissue composition (26), and has proved consistent in elderly patients (27). Fan-beam DEXA has also recently been validated (28,29) for measuring FFM and FM. FFM and FM were expressed as an absolute value and as a percentage of total body weight, and were normalized for height as the FFM index (FFMI) and FM index (FMI) calculated as FFM and FM divided by height squared (30).

REE.—REE was measured with an open-circuit indirect calorimeter (Sensor Medics Vmax-229 Metabolic System; Yorba Linda, CA) and a ventilated hood system.

The measurements were taken after an overnight fast, under standardized conditions, with the person lying awake and emotionally undisturbed, completely at rest, comfortably supine on a bed, their head under a transparent ventilated canopy, in a thermally neutral environment (22°C), after at least 8 hours of sleep. Respiratory gas samples were taken every minute for 30–40 minutes, and only measurements from steady states were considered for the analysis. Steady states were defined as time intervals of at least 5 minutes during which average minutes of oxygen consumption and carbon dioxide production changed by less than 10%, and the average respiratory quotient changed by less than 5%.

The calorimeter was calibrated each day before the tests by using a two-point calibration method based on two separate mixtures of known gas content. Carbon dioxide and oxygen concentrations were compared with a span gas (of known oxygen and carbon dioxide content) and pure nitrogen (as the zero level gas). Flow rate was calibrated with a 3-liter syringe, according to the manufacturer’s instructions. The accuracy of the system was tested regularly (twice a month) by repeatedly measuring acetone combustion, and
Being bedridden, patients with PS and controls were all age, height, BMI, FFM, FM, FFMI, and FMI (Table 1). The level of statistical significance for each test was set at a level of 0.05. REE was normalized for FFM variations in all patients by expressing results as means ± standard deviations. Differences in variables between PS patients and controls were also predicted using the Harris–Benedict equation (33), which is widely used in clinical practice and, despite its age (developed in 1919), has proved accurate in predicting REE in elderly women (34). The difference between measured and predicted REE (ΔREE) was correlated with PS area and volume. The independent effect of area and volume on ΔREE was evaluated using the multiple regression model. Patients were considered hypermetabolic when the measured REE exceeded 10% of the predicted REE.

### Results

The elderly people with and without PS were similar in age, height, BMI, FFM, FM, FFMI, and FMI (Table 1). Being bedridden, patients with PS and controls were all severely impaired in ADL, with a Katz Index higher than 4 (Table 2). Cognitive function by SPMSQ was also markedly impaired in both groups (8.5 ± 2.0 in PS vs 7.8 ± 2.9 in controls). Mean PS volume and area were 28.8 ± 22.3 mL and 42.3 ± 34.4 cm², respectively.

No differences emerged between the two groups for number or severity of associated diseases. The Illness Severity Index was 1.7 ± 0.2 in both PS patients and controls, and the Comorbidity Index was 3.8 ± 1.3 and 3.7 ± 1.5, respectively.

Mean leukocyte levels were similar in the two groups. The indices of inflammation (ERS, C-reactive protein, and fibrinogen) were slightly higher in PS patients, but the difference was not statistically significant (Table 3). Mean albumin, prealbumin, and RBP were lower in patients with PS than in controls (Table 3), and patients with PS had a higher prevalence of values below normal range for albumin (95% vs 82%), prealbumin (73% vs 31%), and RBP (78% vs 48%). Daily calorie intake was slightly higher in controls, but the difference was not statistically significant (Table 4). Unadjusted mean REE was significantly higher in patients with PS (1212.5 ± 236.7 vs 1085.5 ± 161.3 kcal/d), even after adjusting for FFM, or expressed per kg of body weight (25.8 ± 6.7 vs 21.1 ± 4.0 kcal/d/kg) (Table 4). The difference between daily calorie intake and REE was

| Table 1. Age, Anthropometric, and Body Composition Indices in Patients Suffering From Pressure Sores (PS) and Controls |
|-----------------|-----------------|-----------------|
| Variable        | PS (N = 23)     | Controls (N = 29) |
| Age, y          | 83.9 ± 7.2      | 83.6 ± 5.6      | .07 |
| Weight, kg      | 47.0 ± 9.2      | 49.8 ± 9.5      | .18 |
| Height, cm      | 158.3 ± 7.7     | 155.9 ± 6.1     | .22 |
| BMI, kg/m²      | 22.1 ± 4.9      | 22.9 ± 4.7      | .53 |
| FFM, kg         | 33.4 ± 5.1      | 33.5 ± 4.1      | .94 |
| FFMI, kg/m²     | 15.7 ± 2.9      | 15.4 ± 2.2      | .68 |
| FM, kg          | 13.6 ± 5.3      | 16.3 ± 6.1      | .09 |
| FFMI, kg/m²     | 6.4 ± 2.6       | 7.5 ± 2.9       | .15 |

* Notes: PS versus Controls: Student’s unpaired t test.

BMI = body mass index; FFM = fat-free mass; FFMI = fat-free mass index [FFM (kg)/height² (m²)]; FM = fat mass; FMI = fat mass index [FM (kg)/height² (m²)].

Table 2. Results of Katz Index of Basic Activities of Daily Living (Katz-ADLs), Cumulative Illness Rating Scale (CIRS), Short Portable Mental Status Questionnaire (SPMSQ), and Braden Scale in Patients With Pressure Sores (PS) and Controls

### Statistical Analysis

Data were analyzed using Systat statistical software, release 11.5, for Windows (SPSS Inc., Chicago, IL), expressing results as means ± standard deviations. Differences in variables between PS patients and controls were evaluated using Student’s unpaired two-sided t test. REE was normalized for FFM variations in all patients by analysis of covariance (32). The level of statistical significance for each test was set at a level of 0.05. REE was also predicted using the Harris–Benedict equation (33), which is widely used in clinical practice and, despite its age (developed in 1919), has proved accurate in predicting REE in elderly women (34). The difference between measured and predicted REE (ΔREE) was correlated with PS area and volume. The independent effect of area and volume on ΔREE was evaluated using the multiple regression model. Patients were considered hypermetabolic when the measured REE exceeded 10% of the predicted REE.

### Table 3. Leukocytes, Erythrocyte Sedimentation Rate (ESR), C-Reactive Protein (CRP), Fibrinogen, and Visceral Proteins in Patients Suffering From Pressure Sores (PS) and Controls

### Table 4. Energy Intake and Resting Energy Expenditure (REE) in Patients With Pressure Sores (PS) and Controls
negative for both groups, and particularly for patients with PS (−350.2 ± 382.6 vs −157.0 ± 353.2 kcal/d). Hypermetabolism (measured REE > 110% of predicted REE) was seen in 74% of patients with PS and in 38% of controls.

Patients with PS had a difference between measured and predicted REE (ΔREE) that correlated with PS volume (r = 0.58; p < .01, Figure 1), but not with PS area (Figure 2). By multiple regression, the independent effect of the volume on ΔREE was confirmed, whereas area revealed no influence after controlling for volume.

DISCUSSION

Only one recent study has focused on the problem of energy expenditure in elderly patients with PS (16). This is due to the difficulty of finding a homogeneous model for evaluating the effect of PS on REE independently of associated conditions, disability, comorbidity, or infections. Reference methods for investigating body composition and REE also meet with problems in their application to elderly patients.

Our sample of PS cases was small because we adopted strict selection criteria to rule out any factors (other than the sores) capable of affecting energy metabolism. As our patients with PS and our controls were comparable in terms of anthropometric and body composition characteristics, any differences in their nutritional requirements can be attributed to the PS.

All recruited patients were without acute diseases interfering with nutritional status and energy metabolism. The CIRS scale showed a low Illness Severity Index in both groups, and the Comorbidity Index indicated about four conditions causing moderate or worse impairment due to chronic conditions such as urinary and fecal incontinence, mental deterioration, and arthrosis. Moreover, no significant differences emerged between the two groups for serum indices of inflammatory states. Unfortunately, more specific markers of inflammation, such as high-sensitivity CRP, interleukin-1, and interleukin-6, were not measured in our patients.

Signs of malnutrition emerged in both of the groups: Mean albumin values were below the normal range of 35 g/L (35), and 35% of the PS patients and 27% of the controls had a BMI < 20, which is considered a suitable cut-off for defining underweight state in elderly persons (36). Dietary intake was also insufficient in both patients and controls, although the patients received help in eating and had nursing and medical assistance. Probably, their poor nutritional condition was partially attributable to their disability and bedridden state, which are considered predisposing factors in the elderly population (37).

Patients with PS are often malnourished, with lean body mass loss (38). Compared with controls, our patients with PS had no decrease in FFM, but they presented more marked signs of protein malnutrition (lower albumin, prealbumin, and RBP levels).

The low serum proteins in our patients, already found in previous studies (39), could be both a cause and an effect of their PS. Previous studies showed that PS develop particularly in people with albumin values below 30 g/dL (40), but visceral proteins might also drop further after the onset of PS due to exudates from the wound (41) and an increased protein catabolism (42).

While analyzing the difference between daily energy intake and REE, a negative energy balance emerged in both groups, irrespective of the energy cost of the diet-induced thermogenesis and limited physical activity of all patients, although patients with PS had more markedly negative values (Table 4). As energy intake was similar in the two groups, the main reason for a worse energy balance in patients with PS was attributable to their higher REE: Expressed per kilogram of body weight, REE was higher in patients with PS and indicated a hypermetabolic state.

Our results are similar to those of previous studies of paraplegic patients. Alexander and colleagues (11) found higher REE values in 14 paraplegic men with PS than in men without sores (25.9 ± 1.2 vs 21.4 ± 0.6 kcal/d/kg). An increased REE in paraplegic patients with PS was also found by Liu and colleagues (13) (24.3 ± 1.1 vs 20.9 ± 0.8 kcal/d/kg) and Aquilani and colleagues (12) (23.7 ± 4.5 vs 19.6 ± 2.2 kcal/d/kg).

Age-related body composition changes may affect the assessment of REE and hypermetabolism in elderly persons. The decrease in FFM and its metabolically active components with aging leads to a lower REE (43); in a previous
study, moreover, FFM metabolic activity declined in underweight disabled elderly patients, and REE correlated inversely with disability in ADL (15).

Thus, to evaluate the effect of sores on energy metabolism, REE should be adjusted for FFM and results compared with those of patients without PS who have a similar level of physical activity. In our study, a higher REE in patients with PS was confirmed even when it was corrected for FFM using the covariance method (32).

In a recent report from Dambach and colleagues (16) investigating the energy requirements in elderly patients suffering from PS, the authors found no difference in REE between patients with PS and controls (20.7 ± 2.5 vs 19.6 ± 4.7 kcal/d/kg), and elderly patients with stage 4 PS had lower energy requirements than did those with stage 1 PS. The results from Dambach and colleagues are not easy to compare with ours however, because their patients had stages of PS ranging from 1 to 4, and differences in body composition and FFM were not considered; the authors also said that the energy requirements could be much higher in patients with deep PS. In fact, our patients had stage 3–4 PS and an important increase in REE, exceeding 10% of the predicted values in 74% of patients.

Our results seem to demonstrate that the volume, but not the area, of PS can partially account for differences between measured and predicted REE. Energy needs seem to be influenced more by the volume of tissue loss than by the extent of the skin lesion. The involvement of deep tissues probably leads to a higher energy requirement. The mean volume of the sores in our patients was about 30 mL, and wider or deeper sores could probably further increase REE.

Conclusion
The presence of advanced-stage PS in elderly persons is associated with a hypermetabolic state that is influenced by the volume of the sores, and that may contribute to protein malnutrition.

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