

## ORIGINAL ARTICLE

# Prevalence of malnutrition in 1760 patients at hospital admission: a controlled population study of body composition

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**Abstract— Objective:** Malnutrition, defined as low or excessive body weight, is associated with increased hospital length of stay and cost of care. The purpose of this study was to determine if fat-free mass (FFM) and body fat (BF) differed between patients at hospital admission in Geneva and Berlin and healthy volunteers, and if there is a difference in the prevalence of low FFM (percentile  $P < 10$ ) and high BF (percentile  $P > 90$ ) between patients and volunteers.

**Methods:** In total, 1760 patients (Geneva: 525 men, 470 women; Berlin: 397 men, 368 women) were evaluated for malnutrition by BMI, serum albumin, and FFM and BF, determined by bioelectrical impedance analysis (BIA), and compared to 1760 healthy volunteers matched for age and height, and further compared to FFM and BF percentiles, previously determined in 5225 healthy adults.

**Results:** The prevalence of FFM  $P < 10$  was greater in patients than controls. The prevalence of albumin  $< 35$  g/l (14.9% and 11.2% in Geneva and Berlin patients, respectively) and BMI  $< 20.0$  kg/m<sup>2</sup> was lower than the prevalence of low FFM (31.3% and 17.3%, respectively). The prevalence of high BF in Berlin patients was three-fold the prevalence of volunteers. Twelve and twenty percent of Geneva and Berlin patients, respectively, with normal BMI had high BF, compared to 4% of volunteers.

**Conclusions:** Geneva and Berlin patients had lower FFM and higher BF than age- and height-matched volunteers and a higher prevalence of low FFM and high BF. Serum albumin and BMI underestimated the prevalence of malnutrition in patients at hospital admission. Body composition measurements identified patients with low FFM and low or high BF reserves.

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**Key words:** malnutrition; bioelectrical impedance analysis; fat-free mass; body fat; albumin

## Introduction

In Europe and North America, 40–50% of hospitalized patients are at risk of malnutrition (1–5). Higher rates have been reported in elderly subjects (6, 7). Malnutrition tends to worsen during hospitalization (8). Overweight and obesity has been noted in over 50% of population in Europe and the USA and is associated with increased risk of chronic diseases resulting in increased morbidity during hospitalization (9).

Malnutrition, defined as low or excessive body weight, is common in the hospital setting and is associated with increased hospital length of stay and cost of care (10). Routine nutritional screening of patients for low and excess body weight at hospital admission can, therefore, be cost-saving (11, 12). Nutritional screening tools vary with regard to the risk parameters used and their ability to determine nutritional risk. Increased risk has been as-

sociated with significant weight loss over time, low weight or body mass index, reduction in mid-arm circumference and skinfold measurements, changes in functional status, low serum albumin and reduced food intake.

Although body weight, weight changes (13) and body mass index (BMI) (14) are easily obtainable, they do not provide information on the distribution of fat-free mass and body fat (BF). BMI was shown to be inaccurate to assigning a fatness risk factor to individuals, especially among women (15–17). On the other hand, loss of fat-free mass (FFM) as a result of unintentional weight loss is a marker of malnutrition, because it is a consequence of a negative balance between energy (and protein) needs and intake that occurs over days or weeks. Skeletal muscle atrophy is prevalent in sick (18) and elderly populations (19) and is strongly associated with disability and morbidity (20). Muscle wasting is associated with depletion of FFM but normal body weight and has been documented in many pathologies, including cancer (21), AIDS (22), cardiac cachexia (23), and chronic obstructive pulmonary disease (24). We previously found that low FFM was associated with

increased hospital length of stay (Pichard, unpublished results). Segal et al. (25) demonstrated that adverse risk factor levels (e.g. high blood pressure, cholesterol level or blood glucose) were associated with a high BF rather than with a high BMI. Assessment of body compartments may, therefore, substantially improve the assessment of nutritional risk when normal BMI does not reflect decrease FFM or BF.

The purpose of this controlled population study was to determine if FFM and BF differed between patients at hospital admission in Geneva and Berlin and healthy volunteers, and if there is a difference in prevalence of malnutrition, defined as low FFM and/or high BF, between patients and volunteers.

## Subjects and methods

### Patients

In Geneva, all adult patients admitted to the hospital admission center for medical or surgical reasons and subsequently hospitalized were eligible for inclusion. Every 10th patient who met entry criteria was included in the study during a 3 months period. Nine hundred and ninety-five patients were included, two patients refused to participate in the study. Exclusion criteria were edema, burns, peritoneal- or hemodialysis, rehydration perfusion and major cardio-respiratory resuscitation ( $n=61$ ). Age and gender distribution of patients included in the study did not differ from age of all patients seen in the hospital admission center during the 3 months inclusion period, thus confirming that sample was valid for the admission center. Patients were measured in the hospital admission center within 3 h after admission, by the same two coworkers of the Nutrition Unit.

In Berlin, data were collected in the University Hospital Charité (Departments of Gastroenterology, Rheumatology, Cardiology, Urology and General Surgery) and in the Community Hospital Krankenhaus Zehlendorf (Departments of Gastroenterology, Cardiology and General Surgery) by three trained coworkers. Patients ( $n=806$ ) were measured within 24 h after admission. Thirty-nine patients were excluded from the analysis because of missing data and two patients with  $BMI > 50 \text{ kg/m}^2$  were excluded because of inadequate validation of bioelectrical impedance analysis (BIA) in morbidly obese. Eight subjects in Geneva and Berlin with BMI of  $40\text{--}50 \text{ kg/m}^2$  were included, although greater error rate is expected.

Seventy-four and 77% of Geneva and Berlin patients, respectively, were admitted to Medical Services, with the remaining patients being admitted to Surgical Services.

The study protocol was approved by the Geneva and Berlin University Hospital Ethics Committee and informed consent was obtained from all subjects.

### Volunteers

Healthy adults ( $n=1760$ ), matched for gender, age ( $\pm 2$  years) and height ( $\pm 2 \text{ cm}$ ), were selected from our database ( $n=5635$  healthy adults, age 15–98 years) to serve as volunteer group. Volunteers were recruited in the greater Geneva area and represent the same population as the patients in Geneva (26). Currently, there is no volunteer database of body composition parameters established in Germany. Patients in Berlin were therefore compared to Geneva volunteers (see study limitations).

### Measurements

#### *Anthropometric measurements and bioelectrical impedance analysis*

All measurements were performed during the hospital admission examination. Body height was measured to the nearest 0.5 cm using a stadiometer. Recumbent height was measured in patients who were unable to stand up. Body weight to the nearest 0.1 kg on a chair scale or a hoist with attached weighing device for patients who were bed-ridden. The scales were cross-calibrated weekly.

Body composition was determined by BIA as previously described (27) using a 50 kHz generator (RJL-101<sup>®</sup> analyzers, RJL Systems Inc, Clinton Twp, MI, and BIA 2000-M, Data Input, Frankfurt, Germany (28). Previous studies have established the validity of BIA (29, 30).

FFM was calculated using a previously validated multiple regression BIA equation (30):  $FFM = -4.104 + (0.518 * \text{height}^2 / \text{resistance}) + (0.231 * \text{weight}) + (0.130 * \text{reactance}) + (4.229 * \text{sex (men = 1, women = 0)})$ . Cross-validation of BIA with DXA was excellent,  $r=0.986$ ,  $SEE=1.72 \text{ kg}$ , technical error  $1.74 \text{ kg}$ . This same BIA equation had further been validated in elderly subjects (31) and patients (32).

#### *Percentiles for FFM and body fat*

Patients were assigned an age-appropriate percentile rank for FFM based upon our percentile tables of healthy Swiss subjects ( $n=5255$  subjects between ages 15 and 98 years) (26). Percentile ranks below the 10th percentile ( $P \leq 10$ ) and above the 90th percentile ( $P > 90$ ) were used to define FFM depletion and excess BF, respectively.

#### *Albumin*

Blood samples were routinely drawn at the same time as the samples necessary for diagnosis, but before initiation of IV fluids. Cut-off value for albumin (measured by immunonephelometry (33)) was set at  $< 35 \text{ g/l}$  (normal range  $35\text{--}55 \text{ g/l}$ ).

#### *Statistical analysis*

The results are expressed as mean  $\pm$  standard deviation ( $x \pm SD$ ). The differences between age groups, and

diagnosis classifications were analyzed by analysis of variance (ANOVA), using Statview 5.0. Unpaired *t*-tests were used to compare patients and volunteers. Multiple comparisons procedure was by Fisher's least significant difference method. Multiple regression analysis (trend test) was used to evaluate the association, between age groups and height, weight, BMI, FFM, and % BF. Chi-square tests were used to compare the differences between malnutrition indicators. Statistical significance was set at  $P \leq 0.05$  for all tests.

## Results

The anthropometric characteristics of the volunteers and Geneva and Berlin patients are shown in Table 1. BMIs were similar in Geneva patients and volunteers aged 15–74 years and lower in Geneva patients >75 years. Berlin patients were taller and heavier and had higher BMIs than Geneva patients or volunteers.

The FFM was significantly lower in Geneva than Berlin patients or volunteers (Table 2). Berlin patients aged 15–74 years with higher weights maintained FFM and had higher BF than Geneva patients or volunteers. Berlin men >75 years did not differ in FFM or BMI from Geneva patients. Percentage of BF was higher in Geneva and Berlin patients aged 15–74 years than volunteers and was highest in oldest patients or volunteers.

### Prevalence of low BMI and low FFM

The prevalence of low BMI (<20 kg/m<sup>2</sup>) was higher in Geneva patients than Berlin patients and higher in Geneva or Berlin patients than volunteers (Table 3, Fig. 1). The prevalence of FFM  $P < 10$  was greater in patients than controls and was greater than the prevalence of low BMI. Seventy-five percent of patients with low BMI had low FFM, compared to 33% of volunteers. Furthermore, 31% of Geneva and 25% of Berlin patients with normal BMI fell in the low FFM category, compared to 12% of volunteers. The prevalence of low FFM (31% and 17% in Geneva and Berlin patients, respectively) was higher than the prevalence of serum albumin <35 g/l (15% and 11%, respectively).

Thus the prevalence of low FFM is greater in patients than volunteers in spite of similar BMI in Geneva patients and higher BMI in Berlin patients. These results suggest that nutritional depletion, as indicated by low FFM, is not recognized when patients are evaluated by BMI only.

### Prevalence of high BMI and high FFM

The prevalence of high BMI (>30 kg/m<sup>2</sup>) was greater in Berlin patients than Geneva patients or volunteers (Table 4, Fig. 1). The prevalence of BF

**Table 1** Anthropometric characteristics of healthy volunteers and patients at hospital admission

|   | Age                        |                            |                           |                            | <i>P</i> value for trend |
|---|----------------------------|----------------------------|---------------------------|----------------------------|--------------------------|
|   | 15–34 years                | 35–54 years                | 55–74 years               | ≥75 years                  |                          |
| <b>Men</b>                                |                            |                            |                           |                            |                          |
| <i>Height (cm)</i>                        |                            |                            |                           |                            |                          |
| <i>n</i> <sup>a</sup>                     | 180/153/27                 | 271/165/106                | 351/135/216               | 120/72/48                  |                          |
| Volunteers                                | 176.2±7.7                  | 175.5±7.1                  | 173.7±6.8                 | 169.6±7.3                  | 0.0001                   |
| Geneva                                    | 175.1±7.7                  | 173.2±7.2*                 | 171.5±8.4*                | 168.2±7.2                  | 0.0001                   |
| Berlin                                    | 179.5±8.1 <sup>*,***</sup> | 177.8±6.7 <sup>*,†</sup>   | 175.0±6.6 <sup>*,†</sup>  | 172.1±6.6 <sup>*,***</sup> | 0.0001                   |
| <i>Weight (kg)</i>                        |                            |                            |                           |                            |                          |
| Volunteers                                | 73.1±10.1                  | 76.3±9.8                   | 76.6±10.3                 | 72.5±9.0                   | 0.5381                   |
| Geneva                                    | 70.5±12.3*                 | 73.2±12.9*                 | 74.9±13.4                 | 70.1±12.1                  | 0.3384                   |
| Berlin                                    | 74.4±12.0 <sup>***</sup>   | 84.4±14.4 <sup>**,†</sup>  | 82.3±12.9 <sup>**,†</sup> | 71.4±9.8                   | 0.0256                   |
| <i>Body mass index (kg/m<sup>2</sup>)</i> |                            |                            |                           |                            |                          |
| Volunteers                                | 23.5±2.3                   | 24.8±2.6                   | 25.4±3.2                  | 25.2±3.2                   | 0.0001                   |
| Geneva                                    | 23.0±3.4                   | 24.4±3.9                   | 25.4±4.0                  | 24.7±3.7                   | 0.0001                   |
| Berlin                                    | 23.0±2.6                   | 26.7±4.3 <sup>**,†</sup>   | 26.9±3.7 <sup>**,†</sup>  | 24.1±2.8*                  | 0.7221                   |
| <b>Women</b>                              |                            |                            |                           |                            |                          |
| <i>Height (cm)</i>                        |                            |                            |                           |                            |                          |
| <i>n</i> <sup>a</sup>                     | 149/113/36                 | 195/107/88                 | 270/103/167               | 224/147/77                 |                          |
| Volunteers                                | 165.5±6.6                  | 163.7±6.2                  | 161.5±6.2                 | 157.2±7.0                  | 0.0001                   |
| Geneva                                    | 164.4±7.1                  | 162.5±6.3                  | 159.6±5.8*                | 156.0±6.8                  | 0.0001                   |
| Berlin                                    | 167.3±5.5 <sup>***</sup>   | 165.5±5.6 <sup>*,†</sup>   | 163.3±6.7 <sup>*,†</sup>  | 160.4±7.0 <sup>**,†</sup>  | 0.0001                   |
| <i>Weight (kg)</i>                        |                            |                            |                           |                            |                          |
| Volunteers                                | 59.1±6.7                   | 61.1±8.3                   | 65.1±11.2                 | 62.4±10.6                  | 0.0001                   |
| Geneva                                    | 57.9±9.6                   | 64.1±11.5*                 | 62.7±14.9                 | 57.2±11.5 <sup>**</sup>    | 0.2803                   |
| Berlin                                    | 65.3±15.2 <sup>**,†</sup>  | 73.3±16.9 <sup>**,†</sup>  | 69.3±14.5 <sup>**,†</sup> | 64.2±11.1 <sup>†</sup>     | 0.0501                   |
| <i>Body mass index (kg/m<sup>2</sup>)</i> |                            |                            |                           |                            |                          |
| Volunteers                                | 21.6±2.1                   | 22.8±2.7                   | 24.9±4.1                  | 25.3±4.2                   | 0.0001                   |
| Geneva                                    | 21.4±3.2                   | 24.3±4.2 <sup>**</sup>     | 24.6±5.7                  | 23.5±4.3 <sup>**</sup>     | 0.0011                   |
| Berlin                                    | 23.4±5.5 <sup>*,***</sup>  | 26.8±6.1 <sup>**,***</sup> | 26.0±5.1 <sup>*,***</sup> | 24.9±3.6 <sup>***</sup>    | 0.9116                   |

Unpaired *t*-test between volunteers and patients groups \* $P < 0.05$ , \*\* $P < 0.001$ , Geneva patients vs Berlin patients \*\*\* $P < 0.05$ , † $P < 0.001$ .  
<sup>a</sup>*n* in volunteers/Geneva population/Berlin population.

$P > 90$  was greater in patients than controls and greater than the prevalence of high BMI. The prevalence of high BF in Berlin patients was three-fold the prevalence of controls. Twelve and 20 percent of Geneva and Berlin patients, respectively, with

normal BMI had high BF, compared to 4% of volunteers.

These results suggest that BMI does not reflect FFM and BF reserves in patients, and patients differ in body composition from healthy volunteers.

**Table 2** Body composition characteristics of healthy volunteers and patients at hospital admission

|                           | Age            |                |               |            | <i>P</i> value for trend |
|---------------------------|----------------|----------------|---------------|------------|--------------------------|
|                           | 15–34 years    | 35–54 years    | 55–74 years   | ≥ 75 years |                          |
| <b>Men</b>                |                |                |               |            |                          |
| <i>Fat-free mass (kg)</i> |                |                |               |            |                          |
| Volunteers                | 59.9±6.4       | 60.3±5.9       | 58.4±5.8      | 53.5±5.6   | 0.0001                   |
| Geneva                    | 56.6±7.1**     | 56.0±7.2**     | 54.3±8.0**    | 50.1±6.6** | 0.0001                   |
| Berlin                    | 57.5±7.4       | 60.1±7.8†      | 58.7±7.3†     | 51.2±7.1*  | 0.0001                   |
| <i>Body fat (kg)</i>      |                |                |               |            |                          |
| Volunteers                | 13.3±5.1       | 16.0±5.2       | 18.3±6.0      | 19.0±5.2   | 0.0001                   |
| Geneva                    | 14.0±6.5       | 17.3±7.3*      | 20.6±7.0**    | 20.0±7.1   | 0.0001                   |
| Berlin                    | 16.9±7.1**,**  | 24.3±8.2**,*†  | 23.6±7.4**,*† | 20.2±5.2   | 0.6869                   |
| <i>Body fat (%)</i>       |                |                |               |            |                          |
| Volunteers                | 17.7±4.8       | 20.6±4.6       | 23.4±5.2      | 25.9±5.0   | 0.0001                   |
| Geneva                    | 19.1±5.8*      | 22.7±6.4**     | 26.9±5.6**    | 27.9±6.3*  | 0.0001                   |
| Berlin                    | 22.1±6.9**,**  | 28.2±5.6**,*†  | 28.2±5.4**,** | 28.1±5.2*  | 0.0015                   |
| <b>Women</b>              |                |                |               |            |                          |
| <i>Fat-free mass (kg)</i> |                |                |               |            |                          |
| Volunteers                | 42.7±3.8       | 42.9±4.1       | 42.5±5.2      | 39.1±5.1   | 0.0001                   |
| Geneva                    | 40.2±4.8**     | 42.0±5.0       | 38.9±5.9**    | 35.2±5.7** | 0.0001                   |
| Berlin                    | 42.6±5.8**     | 44.8±7.0*†     | 42.0±6.4†     | 39.2±5.2†  | 0.0001                   |
| <i>Body fat (kg)</i>      |                |                |               |            |                          |
| Volunteers                | 16.5±4.3       | 18.2±5.6       | 22.6±7.4      | 23.4±7.3   | 0.0001                   |
| Geneva                    | 17.7±6.1       | 22.1±7.5**     | 23.8±9.8      | 22.1±7.1   | 0.0001                   |
| Berlin                    | 22.7±10.6**,*† | 28.4±10.7**,*† | 27.2±9.1**,** | 25.0±7.0** | 0.9955                   |
| <i>Body fat (%)</i>       |                |                |               |            |                          |
| Volunteers                | 27.5±4.7       | 29.3±5.6       | 34.0±6.2      | 36.7±6.8   | 0.0001                   |
| Geneva                    | 29.9±5.8**     | 33.7±6.1**     | 36.7±7.1**    | 37.8±6.0   | 0.0001                   |
| Berlin                    | 33.4±7.4**,**  | 37.6±6.5**,*†  | 38.5±6.0**,** | 38.3±5.2   | 0.0006                   |

Unpaired *t*-test between volunteers and patients groups \* $P < 0.05$ , \*\* $P < 0.001$ , Geneva patients vs Berlin patients \*\*\* $P < 0.05$ , † $P < 0.001$ .

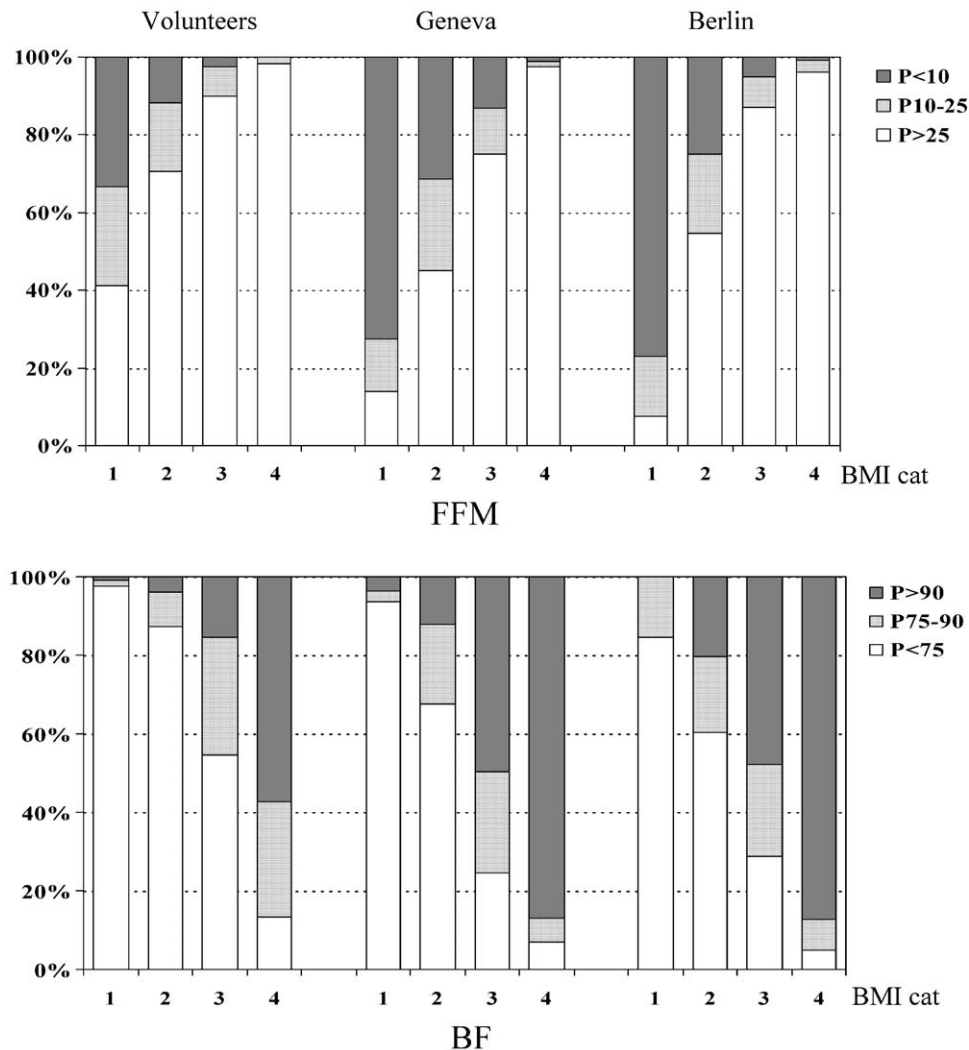
**Table 3** Comparative prevalence of low fat-free mass percentile rank by body mass index (BMI) category in volunteers and patients at hospital admission

| BMI (kg/m <sup>2</sup> ) | Fat-free mass <sup>a</sup>  |                                      |                             | Total% (n) <sup>c</sup> | Chi square<br><i>P</i> value |
|--------------------------|-----------------------------|--------------------------------------|-----------------------------|-------------------------|------------------------------|
|                          | $P < 10\%$ (n) <sup>b</sup> | $P 10\text{--}25\%$ (n) <sup>b</sup> | $P > 25\%$ (n) <sup>b</sup> |                         |                              |
| <b>Volunteers</b>        |                             |                                      |                             |                         |                              |
| ≥ 30                     | 0 (0)                       | 1.7 (2)                              | 98.3 (117)                  | 6.8 (119)               | df = 6                       |
| 25.0–29.9                | 2.6 (15)                    | 7.5 (43)                             | 89.8 (512)                  | 32.4 (570)              | 215.9                        |
| 20.0–24.9                | 11.7 (111)                  | 17.7 (167)                           | 70.6 (667)                  | 53.7 (945)              | < 0.0001                     |
| < 20                     | 33.3 (42)                   | 25.4 (32)                            | 41.3 (52)                   | 7.2 (126)               |                              |
| Total                    | 9.5 (168)                   | 13.9 (244)                           | 76.6 (1348)                 | 100 (1760)              |                              |
| <b>Geneva patients</b>   |                             |                                      |                             |                         |                              |
| ≥ 30                     | 1.2 (1)                     | 1.2 (1)                              | 97.6 (83)                   | 8.5 (85)                | df = 6                       |
| 25.0–29.9                | 13.1 (33)                   | 11.9 (30)                            | 75.0 (189)                  | 25.3 (252)              | 288.6                        |
| 20.0–24.9                | 31.3 (152)                  | 23.7 (115)                           | 45.1 (219)                  | 48.8 (486)              | < 0.0001                     |
| < 20                     | 72.7 (125)                  | 13.4 (23)                            | 14.0 (24)                   | 17.3 (172)              |                              |
| Total                    | 31.3 (311)                  | 17.0 (169)                           | 51.6 (515)                  | 100 (995)               |                              |
| <b>Berlin patients</b>   |                             |                                      |                             |                         |                              |
| ≥ 30                     | 0.8 (1)                     | 3.2 (4)                              | 96.0 (121)                  | 16.5 (126)              | df = 6                       |
| 25.0–29.9                | 5.1 (16)                    | 7.7 (24)                             | 87.2 (272)                  | 40.8 (312)              | 288.4                        |
| 20.0–24.9                | 24.8 (65)                   | 20.6 (54)                            | 54.6 (143)                  | 34.2 (262)              | < 0.0001                     |
| < 20                     | 76.9 (50)                   | 15.4 (10)                            | 7.7 (5)                     | 8.5 (65)                |                              |
| Total                    | 17.3 (132)                  | 12.0 (92)                            | 70.7 (541)                  | 100 (765)               |                              |

<sup>a</sup> Fat-free mass percentiles determined from age and gender appropriate reference tables (see text).

<sup>b</sup> Row total = 100.

<sup>c</sup> Column total = 100.



**Fig. 1** Prevalence (%) of low fat-free mass and high body fat at hospital admission. Prevalence (%) of fat-free mass (FFM) (percentiles- $P$ )  $P < 10$ ,  $P 10-25$  and  $P > 25$  (top) and body fat  $P > 90$ ,  $P 75-90$  and  $P < 75$  (BF) (bottom) in volunteers and Geneva and Berlin patients by BMI category: 1 =  $\leq 19.9$ , 2 = 20–24.9, 3 = 25–29.9 and 4 =  $\geq 30.0$  kg/m<sup>2</sup>. The prevalence of low FFM and high BF was higher in Geneva and Berlin patients than healthy volunteers.

## Discussion

The purpose of a nutritional assessment is to identify patients with depleted body tissues and excess BF and who therefore are likely to be malnourished and at increased risks for complications. This controlled population study extends our previous results (34, 35) and confirms that patients in two European cities are more likely to have low FFM and high BF than age- and height-matched healthy volunteers.

### BMI and nutritional risk

The lower prevalence of patients with a BMI of  $\leq 20$  kg/m<sup>2</sup> or serum albumin  $< 35$  g/l than FFM  $P < 10$  (established in Geneva volunteers (36)) (Table 2) suggests that BMI and serum albumin underestimated the prevalence of nutritional risk.

Although there are limitations in using serum albumin to assess nutritional risk, serum albumin indicates poor outcome in patients. Cano et al. (37) also found FFM was more sensitive for detecting malnutrition than BMI or albumin in respiratory insufficiency patients. Corish et al. (3) found that only 6–7% of patients were identified as malnourished by BMI  $< 20$  kg/m<sup>2</sup> or skinfold measurements  $< 15$ th percentile, whereas 37% had lost  $\geq 10\%$  of body weight. Higher weights and BMIs noted in recent years in the USA and Western Europe may invalidate anthropometric reference standards to define nutritional status. Higher weights and BMIs in recent years have been shown to affect morbidity and mortality and are likely to further influence morbidity and mortality in the future, as the prevalence of obesity increases in Western Europe and the USA.

**Table 4** Comparative prevalence of high body fat percentile rank by body mass index (BMI) category in volunteers and patients at hospital admission

| BMI (kg/m <sup>2</sup> ) | Body fat <sup>a</sup>   |                           |                         | Total% (n) <sup>c</sup> | Chi square<br><br>P value |
|--------------------------|-------------------------|---------------------------|-------------------------|-------------------------|---------------------------|
|                          | P >90% (n) <sup>b</sup> | P 75–90% (n) <sup>b</sup> | P <75% (n) <sup>b</sup> |                         |                           |
| <i>Volunteers</i>        |                         |                           |                         |                         |                           |
| ≥ 30                     | 57.1 (68)               | 29.4 (35)                 | 13.4 (16)               | 6.8 (119)               | df = 6                    |
| 25.0–29.9                | 15.6 (89)               | 29.8 (170)                | 54.6 (311)              | 32.4 (570)              | 540.9                     |
| 20.0–24.9                | 3.8 (36)                | 9.0 (85)                  | 87.2 (824)              | 53.7 (945)              | < 0.0001                  |
| <20                      | 0.8 (1)                 | 1.6 (2)                   | 97.6 (123)              | 7.2 (126)               |                           |
| Total                    | 11.0 (194)              | 16.6 (292)                | 72.4 (1274)             | 100 (1760)              |                           |
| <i>Geneva patients</i>   |                         |                           |                         |                         |                           |
| ≥ 30                     | 87.1 (74)               | 5.9 (5)                   | 7.1 (6)                 | 8.5 (85)                | df = 6                    |
| 25.0–29.9                | 49.6 (125)              | 25.8 (65)                 | 24.6 (62)               | 25.3 (252)              | 415.7                     |
| 20.0–24.9                | 12.1 (59)               | 20.2 (98)                 | 67.7 (329)              | 48.8 (486)              | < 0.0001                  |
| <20                      | 3.5 (6)                 | 2.9 (5)                   | 93.6 (161)              | 17.3 (172)              |                           |
| Total                    | 26.5 (264)              | 17.4 (173)                | 56.1 (558)              | 100 (995)               |                           |
| <i>Berlin patients</i>   |                         |                           |                         |                         |                           |
| ≥ 30                     | 87.3 (110)              | 7.9 (10)                  | 4.8 (6)                 | 16.5 (126)              | df = 6                    |
| 25.0–29.9                | 47.8 (149)              | 23.4 (73)                 | 28.8 (90)               | 40.8 (312)              | 243.2                     |
| 20.0–24.9                | 20.2 (53)               | 19.5 (51)                 | 60.3 (158)              | 34.2 (262)              | < 0.0001                  |
| <20                      | 0 (0)                   | 15.4 (10)                 | 84.6 (55)               | 8.5 (65)                |                           |
| Total                    | 40.8 (312)              | 18.8 (144)                | 40.4 (309)              | 100 (765)               |                           |

<sup>a</sup>Body fat percentiles determined from age and gender appropriate reference tables (see text).

<sup>b</sup>Row total = 100.

<sup>c</sup>Column total = 100.

### FFM and nutritional risk

Our study confirms that FFM depletion and malnutrition are common in patients at hospital admission (1, 2, 8). The prevalence of low FFM was double the prevalence of low BMI, with 31% of Geneva patients and 17% of Berlin patients having low FFM ( $P < 10$ ) (Table 3, Fig. 1). The higher BMIs in Berlin patients appear to be responsible for the lower prevalence of low FFM, compared to Geneva patients. However, the prevalence of low FFM was higher in Berlin patients than in volunteers who had lower mean BMIs. Furthermore, low FFM was common in patients with a BMI in the normal range (20–25 kg/m<sup>2</sup>) and was noted in some overweight patients (BMI 25–29.9 kg/m<sup>2</sup>). Thus a disproportionate number of patients, compared to volunteers, are at nutritional risk due to low FFM.

Higher post-operative complications have been reported in chronic obstructive pulmonary disease patients who had low FFM following lung reduction surgery (38). A positive linear relationship between FFM and physical functioning was observed in men with HIV (39). Patients in the lowest quintile for FFM were more likely to report overall functional disability (40). Sarcopenic (defined as low skeletal muscle mass – 2 SD below normal values) as well as sarcopenic obese patients (defined as both low skeletal muscle mass and BF  $\geq 27\%$  for men and  $\geq 38\%$  for women) were at increased risk for balance and gait abnormalities and falls (41). FFM as a percentage of ideal body weight also exhibited a better correlation with functional parameters such as forced vital capacity, forced expiratory volume

and 6 min walking test than BMI (37). Heitmann et al. (42) confirmed that total mortality was a linear increasing function of low FFM and high BF.

We found that malnutrition, defined as FFM  $P < 10$ , is frequently noted at hospital admission. Covinsky et al. (43) suggested that malnutrition in elderly patients might accelerate the fatal outcome of chronic diseases and places malnourished patients at risk for delayed recovery and/or accelerated functional decline following hospitalization. Volkert (44) demonstrated that the relationship between clinical nutritional assessment and outcomes was independent of other prognostic markers and was valid for patient outcomes other than mortality in elderly patients. The American Institute of Nutrition Committee on Healthy Weights (45) found that lowest nutritional risk was associated with a BMI of 18–23 kg/m<sup>2</sup> in healthy general adult population. However, Schols et al. (46) identified a BMI of 25 kg/m<sup>2</sup> in chronic obstructive pulmonary disease patients as threshold value below which the mortality risk was increased. In elderly subjects, lowest all cause mortality was noted with BMIs of 27–30 kg/m<sup>2</sup> in men and 30–35 kg/m<sup>2</sup> in women and mortality was higher both with lower and higher BMIs (47). The higher mortality rates reported in hospital patients with normal BMIs might be due to unrecognized depletion of FFM. The low FFM noted in our subjects at hospital admission, including patients in the normal BMI range might explain the increased risk of illness and hospitalization. Higher BMIs may be necessary in ill and inactive subjects to maintain FFM above the threshold where functional status is maintained during illness. Weight

loss, which results in loss of both FFM and BF, in combination with pre-existing FFM depletion in patients with low and normal BMI may therefore explain the increased risk of hospitalization and mortality in patients. On the other hand, moderately overweight subjects would be less likely to have low FFM, thus lower mortality. Subcutaneous fat, which is 40–60% of total BF, can be considered an energy buffer that protects against catabolic stress and that is lacking when body weight is low (48). The slightly higher prevalence of high BF in Berlin patients with normal BMI resulted in slightly lower prevalence of low FFM than in Geneva patients. We found that the low FFM is associated with increased length of hospital stay in both Geneva and Berlin patients (unpublished data). We therefore suggest that the low FFM is a contributing factor to patient outcome, which is supported by findings of higher mortality with low FFM (42). If confirmed, public health efforts should be directed at maintaining and increasing FFM by encouraging increased physical activity. Further research is necessary to determine the level of FFM, below which normal functioning is impaired and mortality increases.

FFM depletion is frequently unrecognized because body compartments are not routinely assessed at hospital admission. The lack of recognition of FFM depletion is in part due to higher BF noted in patients compared to controls, which is not identified when only BMI is measured. Therefore, body composition measurements could improve nutritional assessment by assessing FFM and thus identifying those patients who are at risk due to already depleted FFM at hospital admission.

#### *Body fat and nutritional risk*

In spite of small differences in BMI between patients and volunteers, we found significantly higher mean BF and higher prevalence of high BF in Berlin patients and Geneva men between 35 and 74 year than volunteers. Higher weights in Berlin patients and weight gain in probably inactive male patients during middle age resulted in higher BF.

Furthermore, since chronic illness leads to low levels of physical activity, chronic illness, in the absence of loss of appetite, pain and certain drugs, predisposes some patients to weight gain, obesity and high BF. Alternatively, obese subjects have physical limitations caused by impaired respiratory function and musculoskeletal problems, which lead to reduced physical activity (9). Segal et al. (25) demonstrated that high BF was associated with adverse risk factors (hypertension, diabetes). A high percentage of BF was also significantly associated with an increase in total mortality, compared with a low percentage of BF (40). High levels of disability were noted in subjects with high BF ( $\geq 32.0\%$  and  $43.7\%$  in men and women, respectively) (49). Five percent of volunteers, 11% of Geneva and 21% of

Berlin patients fell above the BF mass level. On the other hand, Heitmann et al. (42) found that there was no lower critical BF mass below which total mortality was increased.

The higher proportion of significantly higher fat mass, compared to healthy, age-matched controls, noted at hospital admission suggests that high BF might be a risk factor leading to hospitalization. Further research is necessary to confirm the relationship of high BF with obesity-related illness at hospital admission.

Our study shows that patients differed significantly in body composition from healthy volunteers both in terms of mean FFM and BF and higher prevalence of low FFM and BF. It is not known if patients are more likely to be hospitalized because they have either low FFM or high BF, or if low FFM or high BF are factors that predispose patients to differences in lifestyle, physical activity and consequently increase the risk of disease. Further studies should evaluate the levels of FFM and BF that affect clinical outcome.

#### *Limitations of study*

The percentiles used in this study were developed in healthy Swiss adults. Lack of body composition data for healthy German volunteers is a limitation of this study. Unfortunately, currently no database for body composition exists for German subjects. Median BMI was higher in Berlin than Geneva patients. The median BMI is also higher in healthy German volunteers (age 40–59 years, men:  $27.3 \text{ kg/m}^2$ ; women:  $26.0 \text{ kg/m}^2$ . Mensink GBM: Public Health Survey 1998, personal communications, 2001, Robert Koch Institute, Berlin) than in Geneva volunteers (men:  $23.9 \text{ kg/m}^2$ ; women  $22.1 \text{ kg/m}^2$ ). It must be assumed that percentiles for FFM and BF for German adults would be higher than those reported in this study. However, if reference values were shifted to the right (higher), more German patients would have been FFM depleted and fewer would have had excess BF. The differences in BMI between Geneva and German subjects point out that relevant reference data that are specific for the population in which they are to be used must be developed. The dilemma with percentiles is that they are population specific. The population used to determine percentile ranks may also not necessarily be 'ideal'. Further research should therefore be aimed at determining thresholds for FFM and BF below and above which morbidity and mortality are affected.

The BIA methods used may be criticized, but have been optimized for this study, namely: Water and electrolyte abnormalities are known to influence body composition measurements, including BIA measurements. To limit the impact such an interference, BIA measurements were performed before IV fluids for medications and treatment for dehydration were started, and patients with fluid abnormalities were excluded (see methods). Mild non-visible hydration abnormalities

(overhydration) might have been present in some patients. This would have resulted in overestimation of FFM and underestimation of prevalence of malnutrition.

BIA was validated against dual-energy X-ray absorptiometry. Dual-energy X-ray absorptiometry is not yet universally recognized as a body composition reference method because of methodological problems (e.g. recognition of abnormal hydration) and systematic differences between manufacturers. This does, however, not invalidate the study, because trends in FFM and BF would not be affected by systematic errors (e.g. over- or underestimation of FFM would be the same in all subjects).

A further limitation of this study is that the current climate of hospital cost containment may not be conducive to implementation of new screening and assessment techniques. Although Medical and Surgical Services are likely to be interested in the nutritional status of their patients, it is most likely the Clinical Nutrition Services that would take charge of the nutritional assessment by BIA. Routine body composition measurements, requiring 15–20 min of staff time, could reduce hospital cost by identifying at risk patients and assuring that intervention takes precociously.

## Conclusion

Geneva and Berlin patients had lower FFM and higher BF than age- and height-matched volunteers and a higher prevalence of low FFM and high BF. Serum albumin and BMI underestimated the prevalence of malnutrition in patients at hospital admission. Body composition measurements identified patients with low FFM and low or high BF reserves.

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