Clinical Nutrition (2003) **22(5)**: 473–481

doi:10.1016/S0261-5614(03)00049-9

ORIGINAL ARTICLE

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

U.G. KYLE,* M. PIRLICH,† T. SCHUETZ,† H.J. LUEBKE,‡ H. LOCHS,† C. PICHARD*

**Clinical Nutrition, Geneva University Hospital, Geneva, Switzerland, †Gastroenterology, University Hospital, Charité, Berlin, Germany and , ‡Department of Internal Medicine, Hospital Zehlendorf, Berlin, Germany (Correspondence to: CP, Clinical Nutrition, Geneva University Hospital, 1211 Geneva, Switzerland)*

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^2 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.

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 associated 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 $\mathrm{BMI} > 50\,\mathrm{kg/m^2}$ were excluded because of inadequate validation of bioelectrical impedance analysis (BIA) in morbidly obese. Eight subjects in Geneva and Berlin with BMI of 40–50 $\mathrm{kg/m^2}$ 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 (± 2 years) and height (± 2 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® 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): $\mathrm{FFM} = -4.104 + (0.518 * \mathrm{height}^2/\mathrm{resistance}) + (0.231 * \mathrm{weight}) + (0.130 * \mathrm{reactance}) + (4.229 * \mathrm{sex}\ (\mathrm{men}=1,\ \mathrm{women}=0))$. Cross-validation of BIA with DXA was excellent, $r=0.986$, SEE = 1.72 kg, technical error 1.74 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 g/l (normal range 35–55 g/l).

Statistical analysis

The results are expressed as mean ± standard deviation ($x \pm \mathrm{SD}$). 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 ($<20\,\mathrm{kg/m^2}$) 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 $<35\,\mathrm{g/l}$ (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 ($>30\,\mathrm{kg/m^2}$) 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				*P* value for trend
	15–34 years	35–54 years	55–74 years	≥75 years	
Men					
Height (cm)					
n^a	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	$173.2 \pm 7.2^{*}$	$171.5 \pm 8.4^{*}$	168.2 ± 7.2	0.0001
Berlin	$179.5 \pm 8.1^{*,***}$	$177.8 \pm 6.7^{*,\dagger}$	$175.0 \pm 6.6^{*,\dagger}$	$172.1 \pm 6.6^{*,***}$	0.0001
Weight (kg)					
Volunteers	73.1 ± 10.1	76.3 ± 9.8	76.6 ± 10.3	72.5 ± 9.0	0.5381
Geneva	$70.5 \pm 12.3^{*}$	$73.2 \pm 12.9^{*}$	74.9 ± 13.4	70.1 ± 12.1	0.3384
Berlin	$74.4 \pm 12.0^{***}$	$84.4 \pm 14.4^{**,\dagger}$	$82.3 \pm 12.9^{**,\dagger}$	71.4 ± 9.8	0.0256
Body mass index (kg/m^2)					
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	$26.7 \pm 4.3^{**,\dagger}$	$26.9 \pm 3.7^{**,\dagger}$	$24.1 \pm 2.8^{*}$	0.7221
Women					
Height (cm)					
n^a	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	$159.6 \pm 5.8^{*}$	156.0 ± 6.8	0.0001
Berlin	$167.3 \pm 5.5^{***}$	$165.5 \pm 5.6^{*,\dagger}$	$163.3 \pm 6.7^{*,\dagger}$	$160.4 \pm 7.0^{**,\dagger}$	0.0001
Weight (kg)					
Volunteers	59.1 ± 6.7	61.1 ± 8.3	65.1 ± 11.2	62.4 ± 10.6	0.0001
Geneva	57.9 ± 9.6	$64.1 \pm 11.5^{*}$	62.7 ± 14.9	$57.2 \pm 11.5^{**}$	0.2803
Berlin	$65.3 \pm 15.2^{**,\dagger}$	$73.3 \pm 16.9^{**,\dagger}$	$69.3 \pm 14.5^{**,\dagger}$	$64.2 \pm 11.1^{\dagger}$	0.0501
Body mass index (kg/m^2)					
Volunteers	21.6 ± 2.1	22.8 ± 2.7	24.9 ± 4.1	25.3 ± 4.2	0.0001
Geneva	21.4 ± 3.2	$24.3 \pm 4.2^{**}$	24.6 ± 5.7	$23.5 \pm 4.3^{**}$	0.0011
Berlin	$23.4 \pm 5.5^{*,***}$	$26.8 \pm 6.1^{**,***}$	$26.0 \pm 5.1^{*,***}$	$24.9 \pm 3.6^{***}$	0.9116

Unpaired *t*-test between volunteers and patients groups $^{*}P < 0.05$, $^{**}P < 0.001$, Geneva patients vs Berlin patients $^{***}P < 0.05$, $^{\dagger}P < 0.001$.
[a] *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				*P* value for trend
	15–34 years	35–54 years	55–74 years	≥ 75 years	
Men					
Fat-free mass (kg)					
Volunteers	59.9 ± 6.4	60.3 ± 5.9	58.4 ± 5.8	53.5 ± 5.6	0.0001
Geneva	$56.6 \pm 7.1^{**}$	$56.0 \pm 7.2^{**}$	$54.3 \pm 8.0^{**}$	$50.1 \pm 6.6^{**}$	0.0001
Berlin	57.5 ± 7.4	$60.1 \pm 7.8^{\dagger}$	$58.7 \pm 7.3^{\dagger}$	$51.2 \pm 7.1^{*}$	0.0001
Body fat (kg)					
Volunteers	13.3 ± 5.1	16.0 ± 5.2	18.3 ± 6.0	19.0 ± 5.2	0.0001
Geneva	14.0 ± 6.5	$17.3 \pm 7.3^{*}$	$20.6 \pm 7.0^{**}$	20.0 ± 7.1	0.0001
Berlin	$16.9 \pm 7.1^{**,***}$	$24.3 \pm 8.2^{**,\dagger}$	$23.6 \pm 7.4^{**,\dagger}$	20.2 ± 5.2	0.6869
Body fat (%)					
Volunteers	17.7 ± 4.8	20.6 ± 4.6	23.4 ± 5.2	25.9 ± 5.0	0.0001
Geneva	$19.1 \pm 5.8^{*}$	$22.7 \pm 6.4^{**}$	$26.9 \pm 5.6^{**}$	$27.9 \pm 6.3^{*}$	0.0001
Berlin	$22.1 \pm 6.9^{**,***}$	$28.2 \pm 5.6^{**,\dagger}$	$28.2 \pm 5.4^{**,***}$	$28.1 \pm 5.2^{*}$	0.0015
Women					
Fat-free mass (kg)					
Volunteers	42.7 ± 3.8	42.9 ± 4.1	42.5 ± 5.2	39.1 ± 5.1	0.0001
Geneva	$40.2 \pm 4.8^{**}$	42.0 ± 5.0	$38.9 \pm 5.9^{**}$	$35.2 \pm 5.7^{**}$	0.0001
Berlin	$42.6 \pm 5.8^{***}$	$44.8 \pm 7.0^{*,\dagger}$	$42.0 \pm 6.4^{\dagger}$	$39.2 \pm 5.2^{\dagger}$	0.0001
Body fat (kg)					
Volunteers	16.5 ± 4.3	18.2 ± 5.6	22.6 ± 7.4	23.4 ± 7.3	0.0001
Geneva	17.7 ± 6.1	$22.1 \pm 7.5^{**}$	23.8 ± 9.8	22.1 ± 7.1	0.0001
Berlin	$22.7 \pm 10.6^{**,\dagger}$	$28.4 \pm 10.7^{**,\dagger}$	$27.2 \pm 9.1^{**,***}$	$25.0 \pm 7.0^{***}$	0.9955
Body fat (%)					
Volunteers	27.5 ± 4.7	29.3 ± 5.6	34.0 ± 6.2	36.7 ± 6.8	0.0001
Geneva	$29.9 \pm 5.8^{**}$	$33.7 \pm 6.1^{**}$	$36.7 \pm 7.1^{**}$	37.8 ± 6.0	0.0001
Berlin	$33.4 \pm 7.4^{**,***}$	$37.6 \pm 6.5^{**,\dagger}$	$38.5 \pm 6.0^{**,***}$	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 $^{***}P < 0.05$, $^{\dagger}P < 0.001$.

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^2)	Fat-free mass[a]			Total% (*n*)[c]	Chi square
	$P < 10\%$ (*n*)[b]	P 10–25% (*n*)[b]	$P > 25\%$ (*n*)[b]		*P* value
Volunteers					
≥ 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)	
Geneva patients					
≥ 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)	
Berlin patients					
≥ 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)	

[a] Fat-free mass percentiles determined from age and gender appropriate reference tables (see text).
[b] Row total = 100.
[c] Column total = 100.

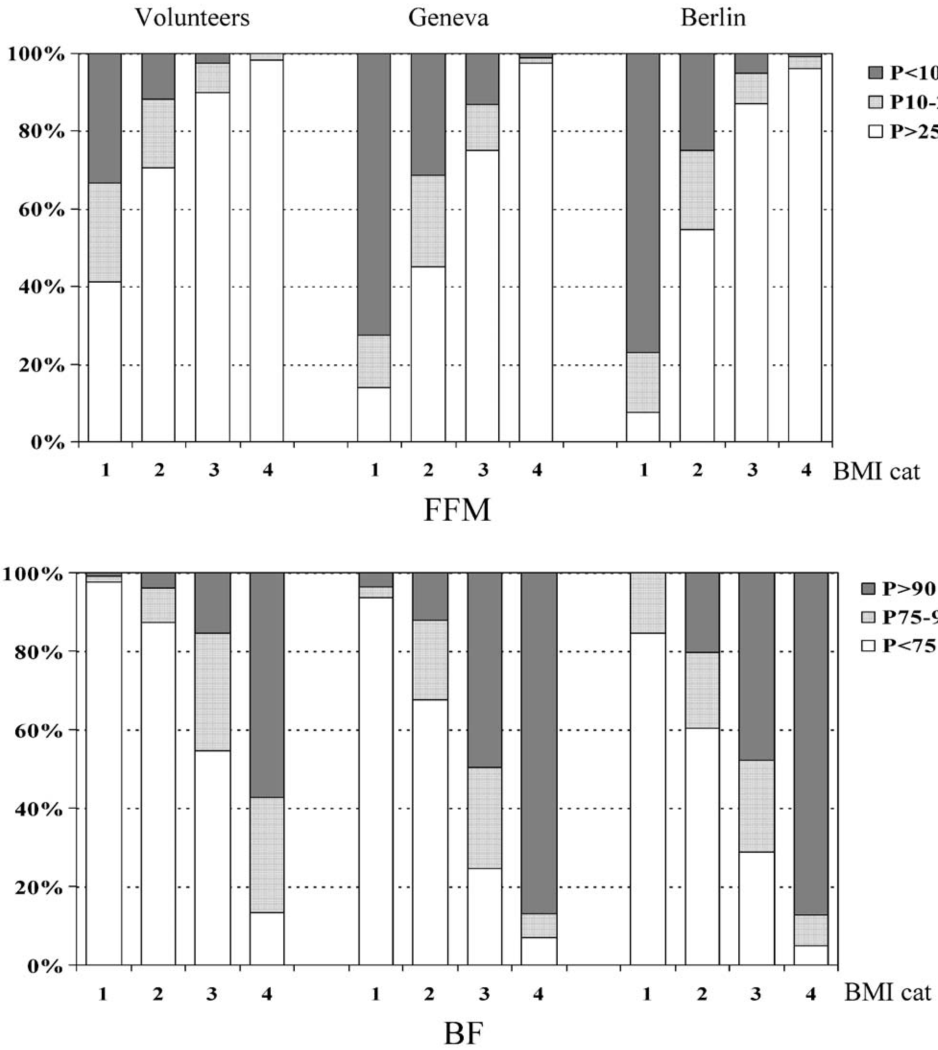

Fig. 1 Prevalence (%) of low fat-free mass and high body fat at hospital admission. Prevalence (%) of fat-free mass (FFM) (percentiles-P) $P<10$, $P10$–25 and $P>25$ (top) and body fat $P>90$, $P75$–90 and $P<75$ (BF) (bottom) in volunteers and Geneva and Berlin patients by BMI category: $1=\leq 19.9$, $2=20$–24.9, $3=25$–29.9 and $4=\geq 30.0\,\mathrm{kg/m^2}$. 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 $\leq 20\,\mathrm{kg/m^2}$ or serum albumin $<35\,\mathrm{g/l}$ 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 $<20\,\mathrm{kg/m^2}$ or skinfold measurements <15th 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^2)	Body fat[a]			Total% (*n*)[c]	Chi square
	P >90% (*n*)[b]	P 75–90% (*n*)[b]	P<75% (*n*)[b]		P value
Volunteers					
≥ 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)	
Geneva patients					
≥ 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)	
Berlin patients					
≥ 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)	

[a] Body fat percentiles determined from age and gender appropriate reference tables (see text).
[b] Row total = 100.
[c] 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^2) and was noted in some overweight patients (BMI 25–29.9 kg/m^2). 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 ≥27% for men and ≥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^2 in healthy general adult population. However, Schols et al. (46) identified a BMI of 25 kg/m^2 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^2 in men and 30–35 kg/m^2 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 kg/m^2; women: 26.0 kg/m^2. Mensink GBM: Public Health Survey l998, personal communications, 2001, Robert Koch Institute, Berlin) than in Geneva volunteers (men: 23.9 kg/m^2; women 22.1 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.

Acknowledgements

We thank the Foundation Nutrition 2000Plus and the Else-Kröner-Fresenius-Stiftung for their financial support. We are indebted to the dietitians at the Geneva University Hospital for data collection and the staff of the Emergency Center for their collaboration during data collection. We thank Martin Kemps, Niklas Luhmann, and Natalie Minko for data collection in Berlin.

References

1. Edington J, Boorman J, Durrant E R, et al. Prevalence of malnutrition on admission to four hospitals in England. Clin Nutr 2000;19:191–195
2. Bruun LI, Bosaeus I, Bergstad I, Nygaard K. Prevalence of malnutrition in surgical patients: evaluation of nutritional support and documentation. Clin Nutr 1999;18:141–147
3. Corish CA, Kennedy NP. Protein-energy undernutrition in hospital in-patients. Brit J Nutr 2000;83:575–591
4. Middleton MH, Nazarenko G, Nivison-Smith I, Smerdely P. Prevalence of malnutrition and 12-month incidence of mortality in two Sydney teaching hospitals. Int Med J 2001;31:455–461
5. Waitzberg DL, Caiaffa WT, Correia MI. Hospital malnutrition: the Brazilian national survey (IBRANUTRI): a study of 4000 patients. Nutrition 2001;17:573–580
6. Constans T, Bacq Y, Brechot JF, Guilmot JL, Choutet P, Lamisse F. Protein-energy malnutrition in elderly medical patients. J Am Geriatr Soc 1992;40:263–268
7. Sullivan DH, Walls RC, Lipschitz DA. Protein-energy undernutrition and the risk of mortality within 1 y of hospital discharge in a select population of geriatric rehabilitation patients. Am J Clin Nutr 1991;53:599–605
8. McWhirter JP, Pennington CR. Incidence and recognition of malnutrition in hospital. Brit Med J 1994;308:945–948
9. Lean ME, Han TS, Seidell JC. Impairment of health and quality of life using new US federal guidelines for the identification of obesity. Arch Intern Med 1999;159:837–843
10. Martyn CN, Winter PD, Coles SJ, Edington J. Effect of nutritional status on use of health care resources by patients with chronic disease living in the community. Clin Nutr 1998;17: 119–123
11. Sheils JF, Rubin R, Stapleton DC. The estimated costs and savings of medical nutrition therapy: the medicare population. J Am Diet Assoc 1999;99:428–435
12. Reilly JJ, Hull SF, Albert N, Waller A, Bringardener S. Economic impact of malnutrition: a model system for hospitalized patients. J Parent Enteral Nutr 1988;12(4):371–376
13. Reynolds MW, Fredman L, Langenberg P, Magaziner J. Weight, weight change, mortality in a random sample of older community-dwelling women. J Am Geriatr Soc 1999;47: 1409–1414
14. Curtin F, Morabia A, Pichard C, Slosman D. Body mass index compared to dual-energy X-ray absorptiometry: evidence for a spectrum bias. J Clin Epidemiol 1997;50:837–843
15. Morabia A, Ross A, Curtin F, Pichard C, Slosman DO. Relation of body mass index to a dual-X-ray absorptiometry measure of fatness. Brit J Nutr 1999;82:49–55
16. Frankenfield DC, Rowe WA, Cooney RN, Smith JS, Becker D. Limits of body mass index to detect obesity and predict body composition. Nutrition 2001;17:26–30
17. Gallagher D, Visser M, Sepulveda D, Pierson RN, Harris T, Heymsfield SB. How useful is body mass index for comparison of body fatness across age, sex and ethnic groups? Am J Epidemiol 1996;143:228–239
18. Bruera E. Clinical management of anorexia, cachexia in patients with advanced cancer. Oncology 1992;49:35–42
19. Baumgartner RN, Koehler KM, Gallagher D, et al. Epidemiology of sarcopenia among the elderly in New Mexico. Am J Epidemiol 1998;147:755–763
20. Dempsey DT, Mullen JL, Buzby GP. The link between nutritional status and clinical outcome: can nutritional intervention modify it? Am J Clin Nutr 1988;47:352–356
21. Costelli P, Baccino FM. Cancer cachexia: from experimental models to patient management. Curr Opin Clin Nutr Metab Care 2000;3:177–181
22. Von Roenn JH, Armstrong D, Kotler DP, et al. Megestrol acetate in patients with AIDS-related cachexia. Ann Int Med 1994;121:393–399
23. Paccagnella A, Calò MA, Caenaro G, et al. Cardiac cachexia: preoperative and post operative nutrition management. J Parent Enteral Nutr 1994;18:409–416
24. Engelen MPKJ, Schols AMWJ, Baken WC, Wesseling GJ, Wouters EFM. Nutritional depletion in relation to respiratory and peripheral skeletal muscle function in out-patients with COPD. Eur Resp J 1994;7:1793–1797
25. Segal KR, Dunaif A, Gutin B, Albu J, Nyman A, Pi-Sunyer FX. Body composition, not body weight, is related to cardiovascular disease risk factors and sex hormone levels in men. J Clin Invest 1987;84:1050–1055
26. Kyle UG, Genton LC, Slosman DO, Pichard C. Fat-free and fat mass percentiles in 5225 healthy subjects aged 15 to 98 years. Nutrition 2001;17:534–541
27. Lukaski HC, Johnson PE, Bolonchuk WW, Lykken GL. Assessment of fat-free mass using bioelectrical impedance measurements of the human body. Am J Clin Nutr 1985;41: 810–817
28. Houtkooper LB, Lohman TG, Going SB, Howell WH. Why bioelectrical impedance analysis should be used for estimating adposity. Am J Clin Nutr 1996;64:436S–448S

29. Gudivaka R, Schoeller D, Kushner RF. Effects of skin temperature on multifrequency bioelectrical impdance analysis. J Appl Physiol 1996;81:838–845
30. Kyle UG, Genton L, Karsegard L, Slosman DO, Pichard C. Single prediction equation for bioelectrical impedance analysis in adults aged 20–94 yrs. Nutrition 2001;17:248–253
31. Genton LC, Karsegard VL, Kyle UG, et al. Comparison of four bioelectrical impedance analysis formulas in healthy elderly adults. Gerontology 2001;47:315–323
32. Kyle UG, Genton L, Mentha H, Nicod L, Slosman D, Pichard C. Reliable bioelectrical impedance analysis estimate of fat-free mass in liver, lung and heart transplant patients. J Parent Enteral Nutr 2001;25:45–51
33. Fink PC, Romer M, Haeckel R, et al. Measurement of proteins with the Behring Nephelometer. A multicentre evaluation. J Clin Chem Clin Biochem 1989;27:261–276
34. Kyle UG, Morabia A, Unger P, Slosman D, Pichard C. Contribution of body composition to nutritional assessment at hospital admission in 995 patients: a controlled population study. Brit J Nutr 2001;86:725–731
35. Kyle UG, Unger P, Dupertuis Y, Karsegard L, Genton L, Pichard C. Body composition in 995 acutely ill or chronically ill patients at hospital admission: a controlled population study. J Am Diet Assoc 2002;102:944–955
36. Schutz Y, Kyle UG, Pichard C. Fat-free mass index and fat mass index percentiles in Caucasians aged 18–94 y. Int J Obesity Rel Metab Disord 2002;26:953–960
37. Cano NJM, Roth H, Court-Fortune I, et al. Nutritional depletion in patients on long term oxygen therapy or home mechanical ventilation. Eur Resp J 2002;20:1–8
38. Nezu K, Yoshikawa M, Yoneda T, et al. The effect of nutritional status on morbidity in COPD patients undergoing bilateral lung reduction surgery. Thorac Cardiovasc Surg 2001;49:216–220
39. Wilson IB, Roubenoff R, Knox TA, Spiegelman D, Gorbach SL. Relation of lean body mass to health-related quality of life in persons with HIV. J Acquir Immune Defic Syndr 2000;24(2): 137–146
40. Broadwin J, Goodman-Gruen D, Slymen D. Ability of fat and fat-free mass percentages to predict functional disability in older men and women. J Am Geriatr Soc 2001;49:1641–1645
41. Baumgartner RN. Body composition in healthy aging. Ann NY Acad Sci 2000;904:437–448
42. Heitmann BL, Erikson H, Ellsinger BM, Mikkelsen KL, Larsson B. Mortality associated with body fat, fat-free mass and body mass index among 60-year-old Swedish men-a 22-year follow-up. The study of men born in 1913. Int J Obesity Rel Metab Disord 2000;24:33–37
43. Covinsky KE, Martin GE, Beyth RJ, Justice AC, Sehgal AR, Landefeld CS. The relationship between clinical assessments of nutritional status and adverse outcomes in older hospitalized medical patients. J Am Geriatr Soc 1999;47:532–538
44. Volkert D, Kruse W, Oster P, Schlierf G. Malnutrition in geriatric patients: diagnostic and prognostic significance of nutritional parameter. Ann Nutr Metab 1992;36:97–112
45. AIN Healthy Weight Steering Committee. Report of the American Institute of Nutrition (AIN) Steering Committee on Healthy Weight. J Nutr 1994;124:2240–2243
46. Schols AM, Slangen J, Volovics L, Wouters EF. Weight loss is a reversible factor in the prognosis of chronic obstructive pulmonary disease. Am J Resp Crit Care Med 1998;157:1791–1797
47. Allison DB, Zannolli R, Faith MS, et al. Weight loss increases and fat loss decreases all-cause mortality rate: results from two independent cohort studies. Int J Obesity 1999;23:603–611
48. Baumgartner RN, Heymsfield SB, Roche AF. Human body composition and the epidemiology of chronic disease. Obes Res 1995;3:73–95
49. Visser M, Harris TB, Langlois J, et al. Body fat and skeletal muscle mass in relation to physical disability in very old men and women of the Framingham Heart Study. J Gerontol A Biol Sci Med Sci 1998;53:M214–M221

Submission date: 26 October 2002 *Accepted:* 17 March 2003