International Journal of Body Composition Research 2006 Vol. 4 No. 3: 123–128 © Smith-Gordon

Submitted 17 March 2005, accepted after revision 17 August 2006

Body composition: the fat-free mass index (FFMI) and the body fat mass index (BFMI) distribution among the adult Austrian population – results of a cross-sectional pilot study

Babak Bahadori[1]*, Elisabeth Uitz[1]*, Katayoun Tonninger-Bahadori[2], Iris Pestemer-Lach[3], Markus Trummer[1], Rene Thonhofer[1], Helmuth Brath [4] and Erich Schaflinger[1]

[1]Department of Internal Medicine, State Hospital, Muerzzuschlag;[2]Department of General Surgery, Division of Pediatric Surgery, State Hospital,Oberwart; [3]Obesity Research Centre, Mitterdorf; [4]Diabetes Outpatients Clinic, GZ-Sued, Vienna, Austria.
*BB and UE contributed equally to this work.

Objective**:** It has been proven that low and high body mass index (BMI) values increase health risks and mortality, and are associated with variations in fat-free mass (FFM) and body fat mass (BF). Fat-free mass index (FFMI; kg/m^2) and body fat mass index (BFMI; kg/m^2) however are better measures of body composition. FFMI and BFMI being age-, sex- and population-specific, are more exact and informative measures. The purpose of this pilot study was to determine FFMI and BFMI values in subjects with normal, overweight, and obese BMI in Austria.

Methods**:** We measured the levels of FFM and BF in 153 healthy Caucasian men and 451 healthy Caucasian women between the ages of 18 to 80 years, using multi-frequency bioelectrical impedance analysis. FFMI, BFMI, and %BF were then calculated for each subject.

Results**:** Predicted FFMI values were 18.1 to 21.7 kg/m^2 for men and 15.1 to 17 kg/m^2 for women within the normal BMI ranges (18.5-24.9 kg/m^2). Predicted BFMI values were 1.5 to 5.0 kg/m^2 for men and 3.4 to 8.0 kg/m^2 for women within the normal BMI ranges. BFMI values were above 8.0 and 11.7 kg/m^2 in men and women, respectively, for obese BMI (>30 kg/m^2). Normal ranges for %BF were 11.9 to 22.7 and 20.8 to 31.0 for men and women, respectively.

Conclusion: A major finding of this study was that a significant number of individuals had a lower FFMI and a higher FMI than predicted for their weight indicating the necessity of body composition measurements in the clinical practice to optimize diagnosis and treatment.

Key words: bioelectrical impedance analysis, fat-free mass, body fat, fat-free mass index, fat mass index, body composition, sex, obesity.

Introduction

Obesity and obesity-related diseases are among the most prominent health problems in Western countries. In the USA and Europe, more than 40% of the population is overweight [1]. Obesity is normally defined by the body mass index (BMI; kg/m^2). BMI values between 18.5 and 24.9 kg/m^2 are considered normal; individuals with BMI values from 25 to 29.9 kg/m^2 are considered overweight, while those with values over 30 kg/m^2 are considered obese [2]. The wide spread use of BMI to define the level of obesity is popular not because it is the 'best way' but because it is the 'easiest way' to achieve a workable indication. The limitations of BMI have been recognized for many years. BMI does not provide information on either fat-free mass (FFM; kg) or body fat (BF; % or kg). Because research has indicated that body composition is a primary determinant of health [3], and a better predictor of mortality risk than BMI [4], FFM and BF compartments should be determined as part of a health assessment.

Until now it has been customary to use absolute FM (kg) and %BF to evaluate nutrition status [4–6]. Because appropriate FFM and BF vary with height, weight and age, it is difficult to determine whether individual subjects have low or high FFM or BF. The use of FFM in absolute terms complicates interpretation because FFM is closely related to height and decreases with age. Variations of FFM and BF with age and height also make it difficult to establish desirable ranges.

Address for correspondence: Babak Bahadori, MD, State Hospital Muerzzuschlag, Division of Metabolism and Nutrition, Grazerstrasse 63-65, A-8680 Muerzzuschlag', Austria.
Tel.: +43-3852-2080-2586 Fax.: +43-3852-2080-2304
E-mail: babak.bahadori@lkh-muerzzuschlag.at

The defects of the percentage fat approach were realized in 1990, when Van Itallie and colleagues recommended that fat-free mass and fat mass should each be normalized separately for height [4]. Both fat-free mass and fat mass can be divided by height squared, to give the fat-free mass index (FFMI) and the fat mass index (FMI). Such a model allows independent evaluation of both fat-free mass and fat mass relative to body size. This approach was subsequently adopted by Hattori et al [7], who devised an extremely informative chart by plotting FFMI on the x axis and FMI on the y axis. Additionally Kyle et al clearly showed the usefulness and advantages of measuring FFMI and BFMI [8].

No cross-sectional study has been completed so far to evaluate the distribution of body composition among the Austrian population. The purpose of this population study was to determine FFMI, BFMI and %BF ranges in subjects with low, normal, overweight and obese BMI. Our study presents FFMI and BFMI in 153 healthy men and 451 women aged between 18 and 80 years.

Subjects and methods

Subjects

In a retrospective manner, we analysed the data of 628 healthy subjects (men, women) aged from 18 to 80 years who underwent a voluntarily body composition measurement in our health center as a part of a routine examination for nutrition and sport counselling.

All subjects were outpatient Caucasians without known pathologies or physical handicaps. Subjects were questioned on their use of medications and reasons for visits to their physicians within the past 6 months to eliminate subjects with acute or chronic diseases. Subjects with water or electrolyte imbalances (edema or ascites), or skin abnormalities (eg, pachydermia secondary to hypothyroidism), were excluded.

Anthropometric measurements and BIA

Body weight was determined with a Rowenta® scale and height was measured to the nearest 0.5 cm using a stadiometer. Body composition was determined by bioelectrical impedance analysis (BIA), a method which involves the measurement of bioelectrical resistive impedance (R). This method is based upon the principle that the electrical conductivity of the fat-free tissue mass (FFM) is far greater than that of fat. Determinations of R were made using an electrical impedance plethysmograph with a four-electrode arrangement that induces a painless alternating current in the body. This method is regarded as safe and reliable [10]. Measurements at 5/50/100/200 kHz were obtained using the Bodystat®, Model QuadScan 4000® BIA instrument; current source electrodes were placed on the dorsal surfaces of the hand and foot proximal to metacarpal-phalangeal and metatarsal-phalangeal joints respectively, and voltage-sensing electrodes were placed. Subjects were placed in the supine position with no parts of the body touching another and electrodes placed on the right hand and foot. Subjects were instructed to avoid eating or drinking for 4 hours prior to the test, and to avoid exercise, alcohol, and caffeine for 24 hours prior to the test. The limitations of this method include subjects with abnormal hydration and those at extremes of BMI ranges [11].

Statistical analysis

The program StatView 5 [12] was used for statistical analysis. The results are expressed as mean ± stan-

Table 1. Anthropometric and body composition data in healthy Austrian adults

Age (years)	18–80	18–39	40–59	80
MEN (n)	153	51	72	23
Height (cm)	177.88 ± 6.73	179.64 ± 5.61	177.44 ± 7.43†	174.78 ± 5.87§
Weight (kg)	88.44 ± 21.06	80.22 ± 16.32	95.41 ± 23.98*	87.37 ± 13.49
Body mass index (kg/m^2)	27.85 ± 5.88	24.74 ± 4.09	30.13 ± 6.52†	28.56 ± 3.88§
Fat-free mass (kg)	66.78 ± 10.37	65.91 ± 8.89	68.50 ± 11.87†	63.57 ± 7.79§
Fat-free mass index (kg/m^2)	21.03 ± 2.53	20.36 ± 1.95	21.65 ± 2.92†	20.78 ± 2.08§
Body fat (kg)	21.32 ± 12.60	14.31 ± 8.63	26.17 ± 14.10†	23.79 ± 7.04§
Body fat (%)	22.81 ± 8.00	16.86 ± 6.09	26.31 ± 7.34†	26.81 ± 4.68§
Body fat mass index (kg/m^2)	6.72 ± 3.80	4.39 ± 2.45	8.26 ± 4.18†	7.78 ± 2.21§
WOMEN (n)	451	145	235	71
Height (cm)	165.38 ± 5.95	167.20 ± 5.18	164.36 ± 6.17†	164.72 ± 5.95§
Weight (kg)	81.31 ± 23.60	72.62 ± 22.06	85.07 ± 23.86†	89.18 ± 19.77§
Body mass index (kg/m^2)	29.87 ± 9.22	26.01 ± 7.93	31.66 ± 9.60†	32.90 ± 7.41§
Fat-free mass (kg)	49.53 ± 7.43	48.72 ± 8.20	50.13 ± 7.07	49.22 ± 6.56§
Fat-free mass index (kg/m^2)	18.12 ± 2.64	17.41 ± 2.73	18.58 ± 2.62†	18.12 ± 2.05
Body fat (kg)	31.68 ± 18.16	23.61 ± 16.05	34.93 ± 18.35†	39.95 ±14.77§
Body fat (%)	36.34 ± 10.31	29.75 ± 9.63	0.39 ± 0.09†	43.64 ± 6.88§
Body fat mass index (kg/m^2)	11.72 ± 7.03	8.49 ± 5.80	13.09 ± 7.30†	14.78 ± 5.69§
Weight (kg)		85.45%		

* $P < 0.05$, 18 - 39 vs 40 - 59, analysis of variance. † $P < 0.001$, 40 - 59 vs 80, analysis of variance. § $P < 0.001$.

dard deviation. The differences between age groups were analyzed by analysis of variance with Fisher's protected least-significant difference comparison. Statistical significance was set at $P < 0.05$ for all tests. Best-fit polynomial regressions were determined to enable calculation of predicted FFMI, BFMI, and %BF for each of the following BMIs: 18.5, 20, 25 and 30 kg/m^2. Goodness of fit was verified. Lines were plotted on the regression graph to show the values for normal, overweight, and obese BMI values on the x axis and normal, high, and very high FFMI, BFMI, and %BF values on the y axis. Thus, measured FFMI, BFMI, and %BF values falling below the values for a BMI of 18.5 kg/m^2 were defined as low; measured FFMI, BFMI, and %BF values falling in the range for BMI between 18.5 and 25.0 kg/m^2 were considered normal, and values above that range were considered high and very high.

Results

Table 1 shows the anthropometric and body composition measurements of our study population aged between 18 and 80 years. Height was greatest in the youngest men and women and progressively decreased thereafter. Weight was progressively greater in older than in younger subjects. BMI (Table 1) was progressively higher in older than in younger men and women.

Fat-free mass index (FFMI)

Normal FFMIs were from 18.1 to 21.7 kg/m^2 in men and from 15.1 to 17.0 kg/m^2 in women (Table 2) which again correspond very well with the Swiss study and the study done by van Itallie et al. [4].

Table 2. FFMI, BFMI and % BF Values for various BMI Values in healthy Austrian adults. * FFMI, BFMI and %BF were determined from regression equations shown in Figs 1–4. %BFwas predicted from BFMI ranges determined in column 2.

BMI (kg/m^2)	FFMI (kg/m^2)	BFMI (kg/m^2)	Body fat fat (%)	%BF fat (%)
MEN (n=153				
30.0	24.4	7.9	30.5	26.5
25.0	21.7	5.0	22.7	19.4
20.0	19.0	2.2	14.5	12.1
18.5	18.1	1.5	11.9	9.9
WOMEN (n=451)				
30.0	18.4	11.6	38.2	38.2
25.0	17.0	8.0	31.3	31.0
20.0	15.5	4.5	23.4	23.0
18.5	15.1	3.4	20.8	20.4

BF (%), percentage of body fat; BFMI, body fat mass index; BMI, body mass index; FFMI, fat-free mass index

Body fat mass index (BFMI)

Figure 1 shows the significant positive relation between BMI and BFMI, and Fig. 2 shows the same between BMI and %BF, ie the higher the BMI, the higher the BFMI and %BF. The BFMI values were 1.5 to 5.0 kg/m^2 in men and 3.4 to 8.0 kg/m^2 in women for the normal BMI ranges (Table 2). BFMI increased linearly with BMI.

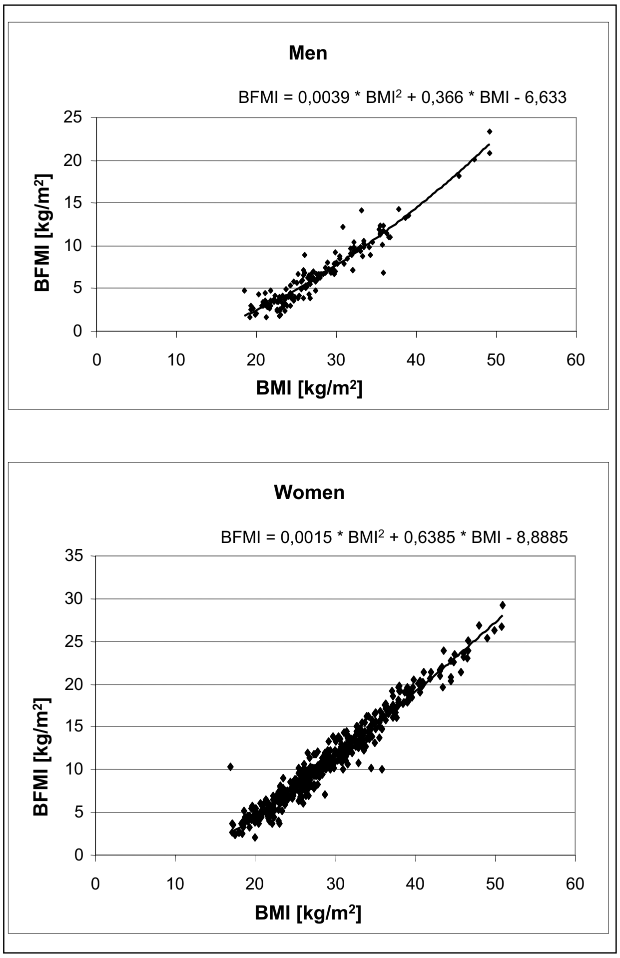

Figure 1. Shows the significant positive relation between BMI and BFMI for men (top) and women (bottom).

Effects of age on FFMI and BFMI

FFMI was lower in elderly men and women. Conversely, FFMI was highest in both men and women 40 to 59 years in comparison with younger subjects (Table 1). FFMI in women older than 60 years was significantly higher than in women 20 to 39 years but did not differ significantly from that of women aged 40 to 60; a similar relationship was noted in men. The relation between FFMI and age was curvilinear, with the highest predicted values peaking at age 65 in men and 53 in women (Fig. 3).

The increase of FFMI in both men and women 40–59 years old in comparison with younger subjects is most probably due to a significant weight gain in this group, which is always associated with an increased lean body mass (LBM) along with FM.

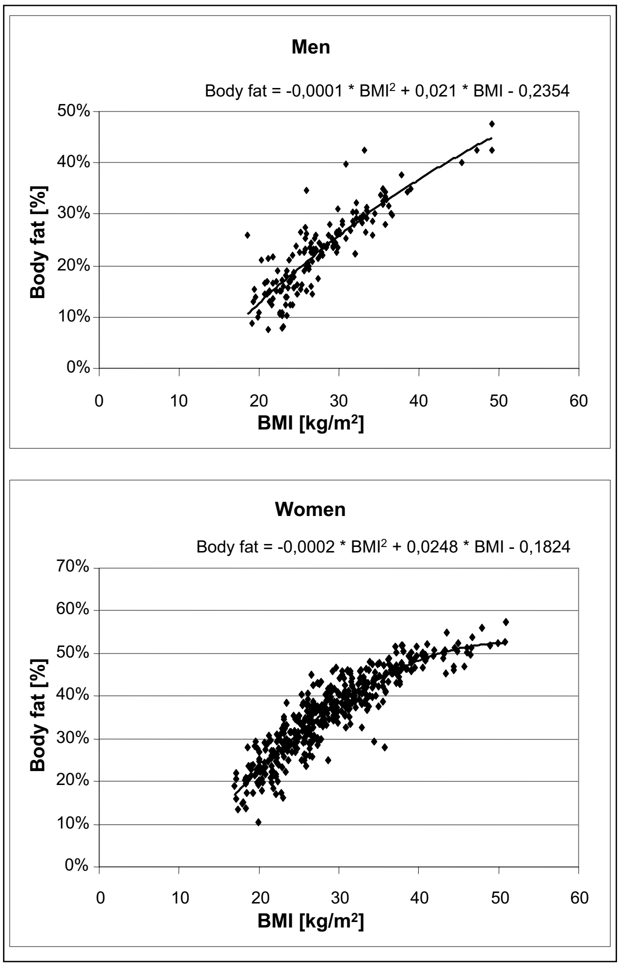

Figure 2. Shows the significant positive relation between BMI and %BF for men (top) and women (bottom).

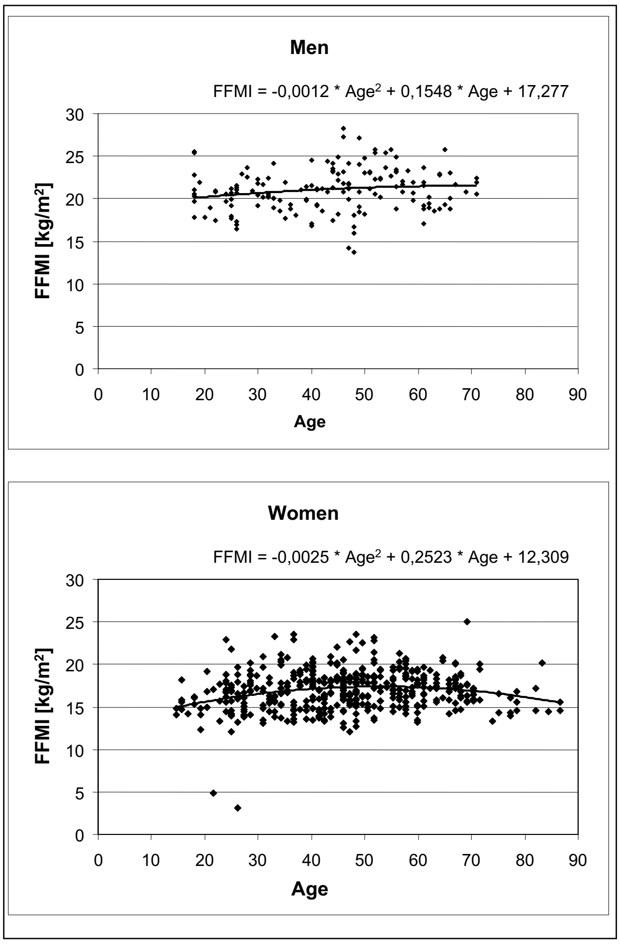

Figure 3. Shows the relationship between FFMI and age for men (top) and women (bottom).

These results are in line with Kyle et al [8] and Forbes et al [13].

In our study the mean BMI of subjects aged 40 to 59 years was 30.1 for men and 30.7 for women while the younger subjects had a mean BMI of 24.7 for men and 26.4 for women. Therefore the higher FFMI values are most probably due to this significant BMI increase. 45.4% of men and 49.0% of women had an FFMI that was below the FFMI predicted for their age – that is, they fell below the regression line depicted in Fig. 3.

FFMI and BMI

Figure 4 shows a significant relation between BMI and FFMI for men (top) and women (bottom). 53.37% of men and 48.17% of women in this study had an FFMI that was below the FFMI predicted for their BMI.

Figure 4 and Table 2 show that predicted FFMIs for subjects in the normal BMI range were 18.1 to 21.7 kg/m² for men and 15.1 to 17.0 kg/m² for women (Table 2). We will refer to these ranges as the 'normal ranges' for FFMI. Analogously, the 'high range' for FFMI refers to the range of predicted values for 'overweight' subjects (BMIs of 25.0 to 29.9 kg/m²) ie 21.7 to 24.4 for men and 17.0 to 18.4 for women. The 'very high range' consists of predicted FFMIs for obese subjects (BMIs in excess of 30) - that is, FFMIs in excess of 24.4 for men and 18.4 for women, respectively.

BFMI, %BF and BMI

The normal range of BFMI values was found to be 1.5 to 5.0 kg/m² for men and 3.4 to 8.0 kg/m² for women. The high ranges were 5.0 to 7.9 for men and 8.0 to 11.6 for women. The very high ranges – corresponding to predicted BMIs for obese subjects – were in excess of 7.9 for men and 11.6 for women. Subjects with normal BMIs generally were in the normal BFMI category, and most overweight subjects were in the high BFMI category. For example, 95.8% (n = 96) of men and 55.2% (n= 55) of women with normal BMIs were in the normal BFMI category, and 98.1% of men (n = 43) and 67.36% of women (n = 130) with overweight BMI were in the high BFMI category. The higher BFMI values of those individuals within the normal BFMI ranges are due to a decreased FFM which agree very well with the increasing sedentary way of life within the Austrian population.

The 'normal' %BF values (Table 2 and Fig. 2) were

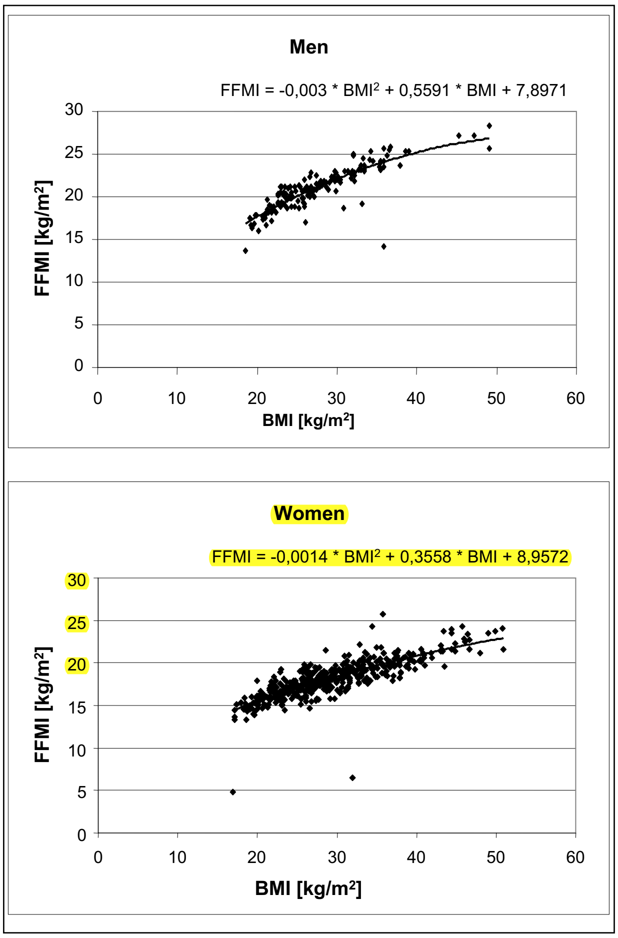

Figure 4. Shows the significant relationship between BMI and FFMI for men (top) and women (bottom).

9.9% to 19.4% for men and 20.8% to 31.0% for women. High %BF values (Table 2 and Fig. 2) were 19.4% to 26.5% for men and 31.0% to 38.2% for women; values exceeding these limits would be considered very high and would correspond to obese BMIs. Further, Table 2 shows hat the %BF in the normal BFMI ranges of 1.5 to 5.0 kg/m^2 in men and 3.4 to 8.0 kg/m^2 in women corresponded to predicted %BF values of 11.9 to 22.7 and 20.8 to 31.3, respectively. The %BF determined from BFMI was very similar to the %BF determined from BMI (Table 2).

Discussion

The classification of under or overweight historically has utilized the comparison of a measured body weight with a range of values considered appropriate for a given height. Reference values are generally based on observed population distributions of measured weight (eg descriptive statistical distributions), such as the National Health and Examination Surveys (NHANES). However, this strategy fails to take into consideration the fact that, at any given BMI, body fatness and muscle mass can vary substantially. On the other hand universal cut-off points of BMI have been challenged [14]. Thus, determination of body composition permits a more precise evaluation of nutritional status and exercise habits.

There is a well-documented association between body composition, morbidity and mortality [15, 16]. The most recent proof was the study done by Kyle et al which clearly showed that subjects with low FFMI and high BMI spend more time in hospital care [17].

Studies have emphasized the importance of determining fat ‘BF’ and lean body mass ‘FFM’ by direct measures, rather than relying on the body mass index (BMI) when describing obesity and malnutrition-related mortality risk and clinical outcome [18].

Lean body mass ‘FFM’ and fat ‘BF’, however, vary with height, weight and age. It is therefore difficult to determine whether individual subjects have low or high FFM or BF using only the absolute values of these parameters. FFMI and BFMI eliminate differences in FFM and BF due to height, and enable us to present one set of recommended ranges, independent of age and height. Thus, FFMI and BFI enable us to make a more precise nutritional assessment. Our study was done as a pilot to establish first trend values within the Austrian population. One of the most interesting findings of this study was the correlation between BMI and FFMI.

Regarding BMI and FFMI 48.17 % for women and 53.37 % of men had lower FFMI values than predicted (Table 2, Fig. 4) whereas BFMI in those individuals was expectedly higher than predicted. This finding is likely due to an increasing sedentary lifestyle and decreasing physical activity in the Austrian population. This trend towards a sedentary lifestyle is quite well documented for other countries [19].

Since FFM has a major impact on resting metabolic rate [20], these findings demonstrate again how important the measurement of body composition in obese individuals seeking treatment is. Such a measurement can only fully be validated in the context of population-based data. Once a physician knows that his patient has a significantly lower FFMI value than predicted, the prescription of proper physical activity, incorporating anaerobic resistance training, can be very useful [21]. On the other hand, the measurement of BFMI and FFMI during weight loss enables the physician to properly monitor progress. Since in a situation in which a patient is losing weight without substantially changing his or her relative body fat (as is the case with crash diets), the calculation of BFMI will quantitatively reveal the amount of body fat store lost. By sharing this knowledge with the patient the physician can motivate patients to continue the prescribed treatment. Another interesting finding of this study was that a significant percentage of women (over 40%) within the normal BMI ranges had a higher BFMI and thus excess fat. These individuals who are usually rated as “low risk” based on BMI are actually at a very high risk for developing metabolic disorders [22]. These data should enable physicians to detect the so-called metabolically-obese normal-weight patient.

Similar to other published studies [23] we found a decline of FFMI in elderly people after the age of 65. Therefore we suggest that the measurement of FFMI should be taken into consideration when assessing the nutritional status of elderly people.

In conclusion, we feel that BMI alone cannot provide information about the respective contributions of FFM and FM to body weight. Instead we suggest the use of FFMI and BFMI provides clinically relevant information about body compartments that is of use to physicians.

References

1. Seidell JC. Obesity, Insulin resistance and diabetes – a worldwide epidemic. Br J Nutr 2000; 83(Suppl):S5–8.
2. World Health Organization. Report of the WHO consultation on obesity. Obesity: preventing and managing the global epidemic. Geneva: World Health Organization, 1998.
3. Segal KR, Dunaif A, Gutin B et al. Body composition, not body weight, is related to cardiovascular disease risk factors and sex hormone levels in men. J Clin Invest. 1987; 84: 1050.
4. Van Itallie TB, Yang M-U, Heymsfield SB, Funk RC, Boileau RA. Height normalized indices of the body's fat-free mass and fat mass: potentially useful indicators of nutritional status. Am J Clin Nutr 1990; 52: 953.
5. Kyle UG, Genton L, Lukaski HC, Dupertuis Y, Slosman DO, Hans D, Pichard C. Comparison of fat-free mass and body fat in Swiss and American adults. Nutr 2005; 21(2): 161–9.
6. Kyle UG, Genton L, Slosman DO, Pichard C. Fat-free and fat mass percentiles in 5225 healthy subjects aged 15 to 98 years. Nutrition. 2001 Jul-Aug; 17(7–8): 534–41.
7. Hattori K, Tatsumi N, Tanaka S. Assessment of body composition by using a new chart method. Am J Hum Biol 1997; 9: 573–8.
8. Kyle UG, Schutz Y, Dupertuis YM, Pichard C. Body composition interpretation: Contributions of the fat-free mass index and the body fat mass index. Nutrition 2003; 19: 59–604.
9. Baumgartner RN, Koehler KM, Gallagher D et al. Epidemiology of sarcopenia among the elderly in New Mexico. Am J Epidemiol 1998; 147:755.
10. Lukaski HC, Johnson PE, Bolonchuk WW, Lykken GI. Assessment of fat-free mass using bioelectrical impedance measuresments of the human body. Am J Clin Nutr 1985 Vol 41(4), 810–17.
11. Kyle UG, Bosaeus I, De Lorenzo AD, Deurenberg P, Elia M, Manuel Gomez J, Lilienthal Heitmann B, Kent-Smith L, Melchior JC, Pirlich M, Scharfetter H, M W J Schols A, Pichard C; ESPEN. Bioelectrical impedance analysis-part II: utilization in clinical practice. Clin Nutr 2004 Dec; 23(6): 1430–53.
12. StatView for Windows; SAS Institute Inc. Copyright © 1992–1998; Version 5.0.1.
13. Forbes GB. Longitudinal changes in adult fat-free mass: influence of body weight. Am J Clin Nutr 1999; 70: 1025–31.
14. Deurenberg P. Universal cut-off BMI points for obesity are not appropriate. Br J Nutr 2001; 85: 135–6.
15. Lahmann PH, Lissner L, Gullberg B, Olsson H, Berglund G. A prospective study of adiposity and postmenopausal breast cancer risk: the Malmo Diet and Cancer Study. Int J Cancer. 2003 Jan 10; 103(2): 246–52.
16. 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 Obes Relat Metab Disord. 2000 Jan; 24(1): 33–7.
17. Kyle UG, Pirlich M, Schuetz T, Lochs H, Pichard C. Low fat-free mass index and very high fat mass index at hospital admission are associated with increased length of stay. Clin Nutr 2002; 21: 11.
18. Segal KR, Dunaif A, Gutin B, et al. Body composition, not body weight, is related to cardiovascular disease risk factors and sex hormone levels in men. J Clin Invest 1987; 84: 1050.
19. Martinez-Gonzalez MA, Martinez JA, Hu FB, Gibney MJ, Kearney J. Physical inactivity, sedentary lifestyle and obesity in the European Union. Int J Obes Relat Metab Disord. 1999 Nov; 23(11): 1192–201.
20. Derumeaux-Burel H, Meyer M, Morin L, Boirie Y. Prediction of resting energy expenditure in a large population of obese children. Am J Clin Nutr 2004 (12); Vol. 80, No. 6, 1544–50.
21. Cuff DJ, Meneilly GS, Martin A, Ignaszewski A, Tildesley HD, Frohlich JJ. Effective exercise modality to reduce insulin resistance in women with type 2 diabetes. Diab Care 2003 Nov; 26(11): 2977–82.
22. St-Onge MP, Janssen I, Heymsfield SB. Metabolic syndrome in normal-weight Americans: new definition of the metabolically obese, normal-weight individual. Diab Care 2004;Sep; 27(9): 2222–8.
23. Schutz Y, Kyle UG, Pichard C. Fat-free mass index and fat mass index percentiles in Caucasians aged 18–98 y. Int J Obes (2002); 26: 953–60.