

Changes in fat free mass in overweight patients with rheumatoid arthritis on a weight reducing regimen. A comparison of eight different body composition methods

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The aim of this work was to compare and validate seven different methods for estimating changes in fat free mass, in patients suffering from rheumatoid arthritis. Measurements were made of fat and fat free mass before and after 12 weeks on an energy restricted, protein rich diet and physical training. The subjects were sixteen female and three male overweight out-patients (mean body mass index at baseline: 30 kg/m²) suffering from rheumatoid arthritis, according to the criteria of the American Rheumatism Association. Fat free mass was estimated by eight different body composition methods (a four-compartment model, total body water, total body potassium, impedance, near infrared interactance, creatinine excretion, body mass index and skinfold measurements).

Mean weight loss was 2.7 kg fat and 1.7 kg fat free mass. There was no difference between measurements of mean change in fat free mass by the four-compartment model and the other methods, except for the creatinine method ($P = 0.03$). Compared to the four-compartment method, the total body water method gave the most accurate estimate of individual fat free mass changes (residual Mean Square: 0.4 kg), second to this method, the impedance method, seemed most valid (residual Mean Square: 0.8 kg). Accuracies of the other methods were lower (residual Mean Square between 1.8 and 19.0 kg).

Of eight methods for estimating changes in FFM, the TBW method gave the most accurate estimate of individual FFM changes, compared to a four-compartment model used as reference. None of the other methods were valid for estimating changes in FFM on an individual level. Estimation of individual changes in fat free mass by most methods may not be sufficient for clinical purposes.

Keywords: fat free mass, rheumatoid arthritis, weight reducing regimen, body composition changes, measurement

Introduction

Estimation of changes in body composition is of importance in a variety of clinical situations, for instance in the assessment of diagnosis, in the evaluation of response to treatment and in the determination of fluid volumes and metabolically active body mass. Also, in subjects undergoing a diet, it would be useful if body composition, rather than simple measures of body weight, could be measured over time in a simple manner.

Subjects suffering from chronic diseases may be overweight but at the same time have relatively less lean mass than overweight subjects free of disease. Recent studies^{1,2} have suggested that this may be the case for patients with rheumatoid arthritis.

Provided the changes in body mass are found mainly in the fat compartment, weight reduction in this group of patients may be of particular value, since the extra weight is a burden to the affected joints. In such patients, it is therefore of particular importance to follow changes in body composition rather than simple changes in body weight.

Whereas changes in body weight can be measured very easily, assessment of changes in body composition is often more difficult. Several sophisticated methods for estimating body composition are presently available. However, many

of these methods are inconvenient, unpleasant, difficult for the subjects to perform, unsuitable for bed-ridden subjects, time consuming or require large and stationary equipment, often of high cost. For these reasons, simpler methods have been developed. A description of the individual differences between estimates of changes in fat free mass (FFM) from various methods was the purpose of the present study. Nineteen overweight patients suffering from rheumatoid arthritis had FFM estimated by eight different body composition methods, before and after 12 weeks on an energy restricted, protein rich diet and physical training.⁴ A four-compartment model⁵ for estimating FFM, based on measures of body weight, height, total body water and total body potassium was used as reference method, and compared to estimates of FFM from total body water (TBW), total body potassium (TBK), impedance (Imp), near infrared interactance (NIR), creatinine excretion (Crea), skinfold measures (Sf) and body mass index (BMI).

Materials and methods

Subjects

The group studied consisted of 16 female and 3 male out-

Table 1 Characteristics of the 19 subjects. Height, weight, body mass index (BMI) and the fat free mass (FFM) were measured at baseline and after 12 weeks on a weight reducing regimen. Measures of body composition (FFM, change in FFM (Δ FFM) and change in body fat mass (Δ BF)) were taken by the four-compartment model. Normal body weights for height are taken from Lindberg *et al.*⁸

	Mean	s.d.	Minimum	Maximum
Age (yrs)	55.7	10.1	34.0	71.0
Height (cm)	165.5	8.2	152.0	187.0
Weight (kg)	82.5	12.9	66.6	111.5
Weight change (kg)	-4.5	2.3	-0.1	-7.5
Normal weight for height (kg)	62.0	5.9	53.2	78.8
BMI _{baseline} (kg/m ²)	30.0	3.0	25.7	35.2
Δ BMI (kg/m ²)	-1.6	0.8	-3.0	-0.1
FFM (kg)	50.1	9.2	39.8	74.2
Δ FFM (kg)	-1.7	2.7	-7.6	3.4
Δ BF (kg)	-2.7	3.8	-10.9	3.4

patients suffering from rheumatoid arthritis, according to the criteria of the American Rheumatism Association.⁶ Duration of disease was 11.1 ± 3.0 years. Average age was 56 (range 35–71) years. Patients were selected from three general hospitals in the Greater Copenhagen Area, were at least 10% overweight, judged by reference values,⁷ and were furthermore motivated for weight loss. Ten of the patients were taking prednisolone in doses from 2.5 to 12.5 mg per day and almost all (15/19) took non-steroid anti-inflammatory drugs (NSAID). During the 12 weeks of the study the patients continued their usual medication. Mean BMI at baseline was 30.0 (range: 25.7–35.2) kg/m². Other characteristics of the subjects, before and after the weight reducing regimen, are given in Table 1.

Reference method

A four-compartment model, described by Bruce *et al.*,⁵ based on measurement of body weight, height, total body water (TBW) and total body potassium (TBK), was used as reference for calculation of FFM. The model calculates body cell mass (BCM) and intra-cellular water (ICW) from TBK, extra-cellular water from BCM and TBW, fat-free extra-cellular-solids (FFECS) from 'normal' body weight for height (BW). FFM is the sum of these three compartments.

Calculation of FFM from either total body water or total body potassium is based on assumptions of constant composition of FFM with respect to water and potassium. The four-compartment model does not rely on these assumptions, but relies on assumptions of constant relations with age between total body potassium and body cell mass (assuming an average potassium/nitrogen ratio of 3 mmol/g, and a protein content of 25% in cellular tissue⁸), between intracellular water and body cell mass (assuming 75% water) and between fat-free extra cellular solids and normal weight for height (assuming that FFECS makes up 12% of normal body weight for height and that dry fat-free-bone weight covers 70% of FFECS).⁵

Total body water

Measurement of total body water (TBW) was carried out by isotope dilution technique.

After emptying the bladder and collecting a sample of urine, all participants were given an oral dose of 3.7 Mbq tritiated water. After 2 h a venous blood sample was taken. During the 2 h equilibrium period no food or drink was allowed. Tritium activity was determined by liquid scintillation counting (Packard Tri-Carb 4530) of plasma. Counting efficiency in plasma was determined by adding a known amount of radioactivity to parallel duplicate samples of plasma. Total body water was calculated by comparison with total activity given. Calculation of FFM from measurement of total body water was based on the assumption that the water content of FFM is 0.73 l/kg.⁹

Total body potassium

Whole body potassium (TBK) was determined by measuring decay of radioactive ⁴⁰K naturally present as a fraction of all potassium. Measurements were performed in a Nuclear Enterprise whole body monitor (NE 8102), equipped with four 6 × 4 inch NaI (TI) scintillation probes, two above and two below the patient support. Before entering the steel-room all participants were asked to wash hair and body, and dress in hospital underwear, to avoid interference from external natural and artificial contamination.

TBK was calculated by comparison with activity in a phantom filled with potassium solution (5.00 g K/kg), the phantom being of equal weight and dimensions as the person measured. Calculation of FFM from measurement of total body potassium was based on the assumption that potassium content of FFM is either 68.1 mmol/kg¹⁰ or 60 mmol/kg in women and 66 mmol/kg in men.¹¹

Electrical impedance

Electrical impedance (R) was measured using a BIA-103 R/L-system-analyser (R/L-systems, Detroit) with a 50 KHz, 800 μ A device, following the instructions given by the manufacturer. Measurements were taken with subjects lying relaxed on a couch, using a tetrapolar electrode placement, with electrodes placed on the dorsal surfaces of the right hand and foot, at the distal metacarpals and metatarsals, respectively, and between the distal prominences of the radius and the ulna at the wrist and the medial

and lateral malleoli at the ankle. Calculation of FFM from measures of impedance was based on equations developed earlier.¹²

Near infrared interactance (NIR)

Measurements of NIR were performed using a NIR-device (Futrex-5000, Futrex Inc, Gaithersburg, Maryland, USA). The instrument uses a single beam rapid scanning monochromator with low level electromagnetic radiation (600 and 2500 nm) and a fibre optic probe. The light is transmitted through the upper right arm, midway on the biceps muscle, at approximately 10 cm from the acromion. A silicon detector measures intensity of the remitted light which is expressed as optical density at the two radiation levels. The procedure has been described by Convey *et al.*¹³ and by Høie *et al.*¹⁴

Urinary creatinine

Creatinine was measured in 24-h urine collected by all patients after careful instruction by trained nurses. Calculation of FFM from measures of urinary creatinine was based on equations developed by Forbes and Bruining.¹⁵

Anthropometry

Skinfolds Right skinfolds (biceps, triceps, subscapular region, suprailium, chest, axilla, thigh and abdomen) were taken in triplicate with a Harpenden Caliper, and the average of each was used for further calculation. Percentage body fat was calculated from sum of biceps, triceps, subscapular region and suprailium (Sf(DW)), based on the equations developed by Durnin and Womersley,¹⁶ and FFM calculated from BF% by subtraction of body fat from body weight. Similarly, equations developed by Pollack¹⁷ were used for calculating FFM from sum of triceps, subscapular region, suprailium, chest, axilla, thigh and abdomen (Sf(Po)).

Height and weight Height (Ht) was measured to the nearest 0.5 cm, with subjects standing without shoes, heels together and head in horizontal Frankfurter plane.

Body weight (BW) was measured to the nearest 0.1 kg, using a SECA scale, with subjects only lightly dressed. Body mass index (BMI) was calculated from height and weight, and FFM estimated from equations developed earlier.¹⁸

In each subject, all measurements of impedance, total body water, total body potassium, height, weight, near infrared interactance and urinary creatinine were carried out on the same day at baseline, before the beginning of the dietary regimen, and at the end of the 12 weeks on diet, when subjects were considered to be in steady state. Measurements of skinfolds were taken within one week of the other body composition measurements.

The weight reducing regimen

The study was initiated by a one week dietary recall, by a dietician. The patients were then instructed to reduce energy intake by 30%, primarily by reducing fat intake to approximately 30 g per day for women and 30–50 g for men. A high protein/low energy, vitamin/mineral supple-

mented preparation (Nutrilett, Nycomed Pharmas Norway)¹⁴ was employed as a dietary supplement to increase protein intake. Five sachets containing a total of 61.5 g high quality protein per day were taken. The weight reducing treatment lasted 12 weeks. After the first week all patients had a brief second interview in order to solve individual adherence problems. Compliance was estimated by one week dietary recalls initially, after 6 weeks and at the end of the study. The reported protein intake was compared to protein oxidation estimated from 24-h urea excretion.¹⁹ Reported energy intake was related to total energy expenditure as calculated by a modification of the factorial method: estimated basal metabolic rate was multiplied by an activity factor calculated according to the patient's reported physical activity during the last week. The different activities were weighed as reported previously.¹⁹ This has been described in more detail elsewhere.⁴

Before the study, aerobic capacity was measured by a bicycle exercise test, carried out for two steady state periods of 10 min each, at 50% and at 65% respectively of the estimated $\dot{V}_{O_2\max}$.²⁰ Heart rate and subjective rating of perceived exertion²¹ were registered at the end of each period. The test was repeated after the study, employing the same absolute work load for each patient.

The physical training programme was adjusted to each patient and took place in the patients' homes minimum three times per week. The programme was composed of dynamic strength and conditioning exercises for approximately 20 min, initiated by 10 min of warming up, and terminated by 5 min of stretching exercises. At non-exercise days the patients were told to take a walk for 30 min. The instruction was given by a physiotherapist before the study, and followed up by the same therapist 1 and 6 weeks into the trial.

Statistical methods

Paired *t*-test was used to evaluate differences between mean values of changes in body composition estimated by different methods. Regression analysis, including estimation of residual mean square and correlation coefficients, was used to show association between reference method and other methods. The test for significant differences between the standard deviations of various methods in Table 3 was performed, correlating the sum of the differences of the individual methods to the difference of the differences of the methods. This procedure has been described earlier.²² Differences were considered statistically significant for values of $P < 0.05$.

The project was approved by the Ethics Committee of Copenhagen, and is in accordance with the Helsinki II declaration.

Results

Reported mean energy intake during the study (6.6 ± 1.6 MJ) was less than calculated mean energy expenditure (9.8 ± 1.6 MJ). At the midway interview, increased protein intake (113 ± 18 g) was equal to measured protein oxidation (114 ± 32 g). At the final interview, protein oxidation

Table 2 Mean, standard deviation (s.d.) and range of the ten FFM estimates (kg) calculated from eight methods at baseline and follow-up, together with a statistical analysis of change in FFM between baseline and follow-up

Method	Fat free mass at baseline (kg)		Fat free mass at follow-up after 12 weeks (kg)		P-value
	Mean \pm s.d.	Range	Mean \pm s.d.	Range	
Reference	50.1 9.2	39.8-74.2	48.4 9.1	40.0-71.8	
TBW	50.9 9.9	40.6-77.3	48.7 9.8	39.6-73.7	0.01
TBK (68.1)	38.6 11.1	26.3-65.7	37.3 10.1	25.2-60.1	0.02
TBK (66/60)	42.5 10.5	29.8-67.8	41.4 9.6	28.6-62.0	0.20
Impedance	49.8 9.2	41.1-75.6	48.6 9.0	40.2-73.8	0.0001
NIR	53.9 9.9	43.1-79.1	52.5 10.4	40.6-78.5	0.001
Creatinine	39.0 9.1	29.8-67.9	36.7 8.3	25.8-63.3	0.03
BMI	51.1 10.3	41.9-80.0	48.1 9.7	37.0-74.3	0.0001
Sf (DW)	49.3 11.9	37.3-78.5	46.7 11.9	36.1-75.2	0.0001
Sf (Po)	52.8 11.8	41.0-80.6	51.5 11.7	40.6-79.7	0.0001

TBW: Total body water, TBK: Total body potassium (equations developed by Forbes *et al.*¹⁰, TBK (68.1); equations developed by Wormsley *et al.*¹¹, TBK (66/60) NIR: near infrared interactance, BMI: Body mass index, sf: Skinfolds (equations developed by Durmin & Womersley¹⁶, Sf(DW); equations developed by Pollack¹⁷, Sf(Po)).

showed a small decrease (101 ± 24 g) and was only slightly less than reported protein intake (112 ± 22 g). All subjects lost weight (range 0.1 kg - 7.5 kg). On average, patients lost 4.5 ± 2.3 kg of which 2.7 ± 3.8 kg was fat and 1.7 ± 2.7 kg lean mass. Six of the nineteen subjects gained an average of 1.1 ± 1.2 kg FFM during the diet regimen.

Table 2 gives mean s.d., minimum and maximum values of the ten FFM estimates calculated from the eight methods. Two different equations were used for calculation of FFM from total body potassium and from skinfold measurements. A paired *t*-test showed that in all methods, except for both methods based on potassium measurements, the difference between baseline and follow-up measure was significant.

Both at baseline and follow-up, the creatinine and the two TBK methods were found to underestimate FFM ($P < 0.0001$) compared to the reference, whereas the NIR method and the skinfold method, based on the equations developed by Pollack,¹⁷ overestimated FFM ($P < 0.007$). No significant differences were seen for the other techniques.

Table 3 gives mean difference and standard deviation (s.d.) between changes in FFM during the 12 weeks diet measured by the reference and the other methods. There

were no significant differences in change in FFM between the reference and the other methods, except for the creatinine method ($P = 0.03$). A comparison of standard deviations in Table 3 showed a significantly smaller standard deviation for TBW than for any other method ($P < 0.0001$). The standard deviation regarding changes in FFM measured by impedance was furthermore found to be lower than those of both skinfold methods (Sf(DW), $P = 0.001$ Sf(Po), $P = 0.006$), the BMI method ($P = 0.04$) and marginally lower than those of the TBK (66/60) ($P = 0.07$) and the creatinine methods ($P = 0.08$). There was no difference between the standard deviations of the impedance, the NIR, and the TBK (68.1) methods, but a lower standard deviation was found for TBK(68.1) than for TBK(66/60) ($P < 0.0001$). Furthermore, Sf(DW) had a larger standard deviation than the NIR ($P = 0.004$) and the BMI method ($P = 0.04$), and the standard deviation of creatinine was higher than those of the NIR ($P = 0.04$) and the Sf(Po) methods ($P = 0.05$).

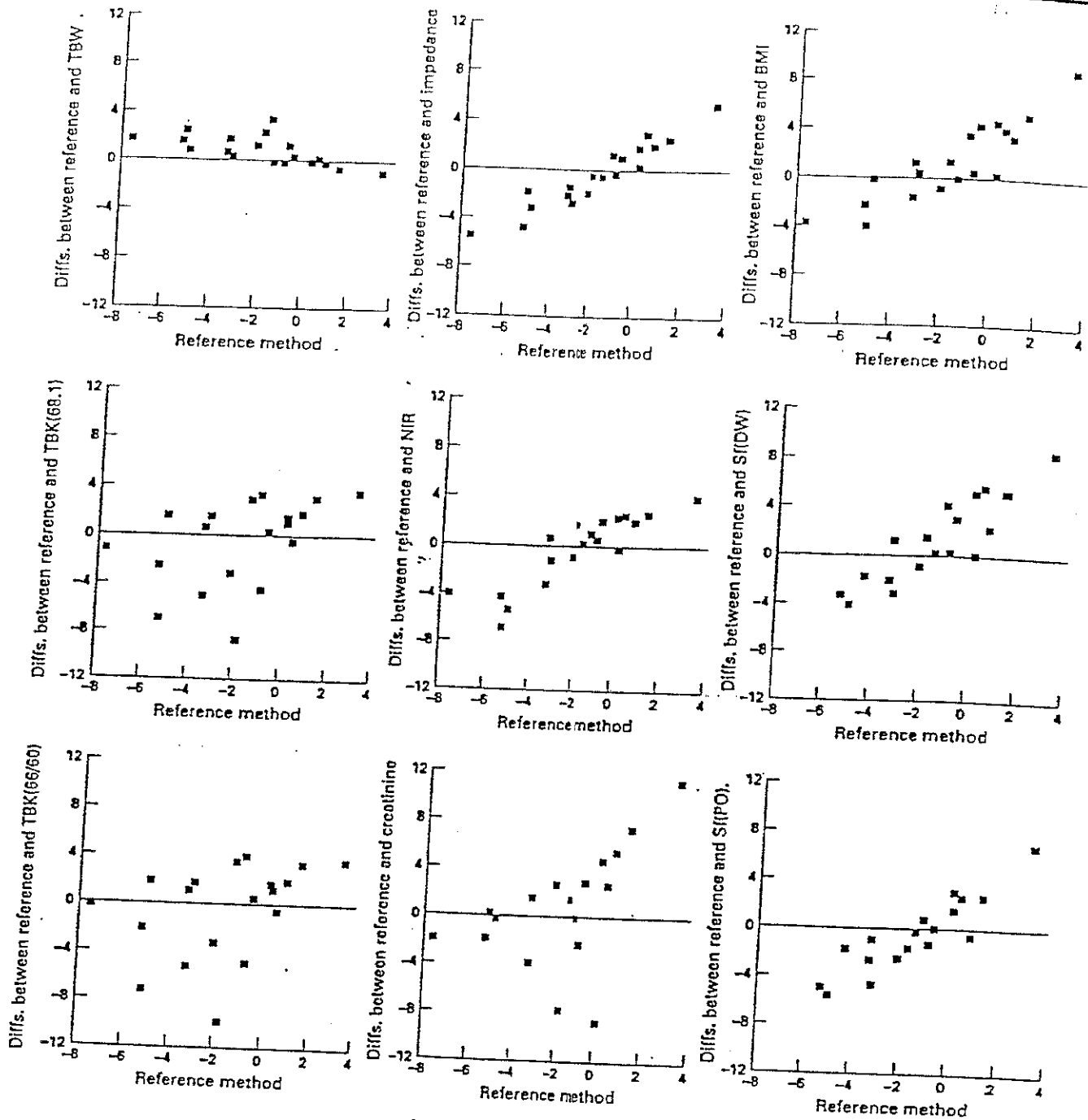
Table 4 gives standard errors (residual mean squares), explained variance (R^2) and Pearson correlations (R) of changes in FFM from the different methods compared to the reference method. There were large differences between

Table 3 Mean, difference and standard deviation between changes in FFM by the reference method and by each of the other methods, before and after 12 weeks on a weight reducing regimen

	Difference in mean change in FFM	
	(kg)	s.d. (kg)
TBW	0.4	1.0
TBK (68.1)	-0.7	3.6
TBK (66/60)	-0.6	3.9
Impedance	-0.5	2.8
NIR	-0.4	3.1
Creatinine	-2.3	4.2
BMI	1.3	3.3
Sf (DW)	1.4	3.6
Sf (Po)	-0.4	3.3

Table 4 Residual mean square and correlation (R) of the change in FFM as measured by the different methods, compared to the reference method

	Residual mean square RES (kg)	Explained variance R^2	Correlation (R)
TBW	0.4	0.97	0.98
TBK (68.1)	11.2	0.12	0.26
TBK (66/60)	13.9	0.12	0.24
Impedance	0.8	0.01	-0.22
NIR	2.1	0.0001	-0.04
Creatinine	19.0	0.01	-0.10
BMI	2.6	0.02	-0.14
Sf (DW)	3.1	0.19	-0.40
Sf (Po)	1.8	0.25	-0.46



One patient developed renal malfunction during follow-up, and was excluded.

Figure 1 Differences between change in FFM measured by the reference and each of the other methods, expressed as functions of change in FFM measured by the reference method. TBW: Total body water, TBK: Total body potassium (equations developed by Forbes *et al.*¹⁰, TBK (68.1), equations developed by Womersley *et al.*¹¹, TBK (66/60); NIR: near Infrared interactance, BMI: Body mass index, Sf: Skinfolds (equations developed by Durnin & Womersley¹⁸, S(DW); equations developed by Pollack¹⁷, S(Po).

these estimates of mean squares, with TBW and impedance methods clearly superior, and creatinine and TBK clearly inferior to other methods.

Figure 1 shows individual differences between reference and other methods expressed as functions of the reference method.²² This was done in order to assess the magnitude

of disagreement between the various techniques. Only TBW showed good agreement with the reference method at the individual level. For the other methods positive relationships were found between the method-differences and the change in FFM, indicating a poor individual agreement between the reference and these other methods.

Discussion

Mean and individual changes

The present study describes a comparison of eight methods for estimating changes in body composition, after a 12 week diet and physical activity, in overweight patients with rheumatoid arthritis.

The study shows that, even though all techniques except the creatinine method gave estimates of *mean* change in FFM similar to the reference estimate, significant differences were seen between the accuracies of the methods which invalidated estimates at the individual level. Similar results have been reported in healthy subjects.²³ Compared to the reference, the TBW method had clearly lower variation, and estimated change in FFM with higher accuracy, than other methods, both at mean and individual level. This is to be expected, as the reference method used was based on measurement of total body water. However, even though the reference method is also based on measurement of total body potassium, this method estimated neither mean nor individual FFM or FFM changes correctly. The four-compartment model assumes that almost all potassium resides intracellularly. Thus TBK depends primarily on the size of BCM. As there is a large variation in BCM within FFM, the poor estimation of mean and individual changes in FFM is presumably explained by larger violation of assumptions when estimating FFM from TBK rather than from TBW, due to larger variations in the potassium content than in the hydration of FFM.²⁴

In the present study, only obese subjects were examined. Compared to lean subjects, the estimation of FFM from total body potassium is underestimated in obese, as the potassium rich body cell mass comprises a smaller fraction of FFM; while TBW-estimated FFM is overestimated because of a higher hydration of FFM in obese than in lean.²⁵ As a consequence of this, with weight loss, FFM changes will be slightly overestimated using TBW and underestimated using TBK methods, as evident when compared with the estimates from the four-compartment model.

Next to TBW, impedance was found to have the highest accuracy for predicting mean changes. However, even though at the individual level, agreement between reference and impedance measures of FFM changes was better than for other methods, Figure 1 shows a substantial difference in loss of FFM between impedance and the reference method. For most subjects, impedance underestimated the true loss of FFM. This has also been found by others.²⁶⁻²⁸ It has been argued that impedance measurements are influenced by the ratio of intracellular to extracellular water.²⁹ This would result in overestimating true FFM loss and underestimating true FFM gain in obese, opposite to what was seen in the present study.

Urinary creatinine excretion is generally considered to be an index of muscle mass³⁰⁻³¹ provided the diet does not contain excessive amounts of preformed creatinine (from meat). Creatinine excretion does, however, vary somewhat from day to day, even during a constant diet or fasting.³² Furthermore, tall individuals excrete more Cr than small individuals. In the present study, the patients furthermore may be expected to have lower muscle mass than healthy

subjects.¹⁻³ Calculation of FFM from creatinine may therefore rely on erroneous assumptions. Poor reproducibility of the creatinine method, incomplete urine collections or day-to-day variations in creatinine excretion may also be responsible for the poor agreement with the reference method.²²

The reference method

The use of the present four-compartment model relies on assumptions of constant intracellular potassium, bone mineral, and intracellular water with age. These assumptions are less subject to inter-individual variation, even under differences in hydration status, than the assumptions of the simpler two-compartment models.⁵ However, although assumptions may to some degree be violated, these violations may be of lesser importance when *change* in body composition is considered. On the other hand, it may be questioned if these assumptions are valid in patients with rheumatoid arthritis. *First*, more than half of the patients in the present study took low dose prednisolone, and almost all took non-steroid anti-inflammatory drugs (NSAID) during the whole course of the diet regimen. In general, however, intracellular potassium concentration remains constant under various conditions,³³⁻³⁴ and specifically it has been found that intracellular potassium and BCM remain unchanged during prolonged cortisone treatment.³⁴⁻³⁵ In accordance herewith the patients taking prednisolone in the present study lost similar amounts of BCM (0.6 ± 2.0 kg compared to 0.5 ± 2.0 kg) as those who did not take this medication. NSAID use did not influence this data. *Second*, bone mineral is often reduced in RA patients.³⁶ However, the estimated change in FFECs would be influenced only if bone mineral decreased during the 12 weeks dietary regimen. A decrease as large as 0.05% per week would theoretically result in an overestimation of FFECs at the follow-up examination, and thereby an underestimation of the FFM change of approximately 0.03 kg. *Third*, ECW may be increased in RA patients. However, there is no reason to believe that estimated *change* in ECW should be invalid in either normal subjects or RA patients. Indeed, there was no difference in loss of ECW per kg FFM between patients taking prednisolone compared to those who did not take this medication (0.40 ± 0.03 l/kg vs 0.41 ± 0.05 l/kg). Similarly, effects on *change* in ECW resulting from hydrogen exchange of tritium with carboxyl and hydroxyl groups³⁷ during the equilibrium of tritium, is probably negligible. Furthermore, the variation in the degree by which TBW is overestimated by tritium is unknown,³³ and varies with the length of the equilibrium time, which in the present study was short (2 h only). The use of the four-compartment model as reference in the present study seems therefore justified.

Measurement errors

Last, but not least, the precision of measuring individual changes over time is dependent on the sum of measurement errors of both initial and later measures. As the reported changes in the present study, as in most studies from the literature, often are small, measurement errors of initial and follow up measurements lead to a relatively large error

when measuring changes.

Assuming precision of body weight and height to be 0.01 kg and 0.5 cm, respectively, and precision of TBW and TBK to be 2% and 3%, respectively,^{23,32} the precision for estimation of FFM from TBW, TBK and the four-compartment model is $\pm 1.2\text{kg}$, $\pm 0.75\text{kg}$ and $\pm 0.43\text{kg}$, respectively. The precision of change in FFM is therefore 1.7 kg, 1.06 kg and 0.61 kg. Thus, in agreement with others,^{23,38} we find that the presently used multi-compartment model has a greater precision than the two-compartment models. Kushner *et al.*³⁹ have estimated that individual changes of less than 1.4 kg FFM may not be shown by any method. Similar findings (less than 1.54 kg) were reported by Jebb *et al.*²³ In the present study, a change of 1.7 kg FFM was found. Thus, the four-compartment model, with its calculated precision of 1.22 kg, should sufficiently capture the changes of FFM in the present study. However, measurement bias of several of the other methods may be too large to estimate FFM changes. Indeed, in a classical substrate balance study, Jebb *et al.*²³ found that individual changes in fat mass estimated by methods like TBW, TBK, BMI, skin-folds and impedance should exceed between 0.81 and 6.05 kg. In the present study somewhat similar bias were found (2.0 kg (TBW) to 8.2 kg (Creatinine)).

The diet regimen

The fine agreement between reported protein intake and oxidation suggests a good compliance throughout the study. However, this can not be used to validate energy intake since a large part of the protein intake, but not energy intake, stemmed from the dietary supplement. The calculated energy balance suggests a daily energy deficit of 3.2 MJ which, in theory, should have resulted in at least 7.1 kg weight loss, assuming the energy equivalent of weight loss is 38 MJ/kg, the energy content of fat. In the present study,

only 4.5 kg was lost, suggesting that self-reported energy intake after all was under-reported, that energy expenditure was overestimated, or both. Furthermore, a more efficient energy utilisation after weight loss has also been reported.⁴⁰ Finally, the weight lost in the present study is comparable to the weight loss of 5.3 kg obtained by obese women, studied for 10 weeks by Bjorvell and Langius⁴¹ in an outpatient regimen consisting of nutritional advice, exercise and behavioural modification.

Conclusions

Of eight methods used for estimating changes in FFM in 19 obese rheumatoid arthritis patients on a 12 weeks weight reducing regimen, the TBW method gave the most accurate estimate of individual FFM changes, compared to the reference method. None of the other methods were valid for estimating changes in FFM on an individual level. Hence, none of these other methods seem sufficient for clinical purposes. However, this conclusion may not apply to normal subjects.

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