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RESTING METABOLIC RATE IN ELDERLY NURSING HOME PATIENTS WITH MULTIPLE DIAGNOSES

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Abstract: Background**:** In the diseased elderly weight loss and malnutrition are common. It is unclear to what degree this is caused by an elevated resting metabolic rate (RMR), a decreased energy intake or a combination of the two. Objective: To measure RMR and nutrient induced thermogenesis (NIT) in chronically diseased elderly living in a nursing home and test for a correlation with fat free mass (FFM), age, energy intake and activities of daily living (ADL). Design: Explorative study performed in the residents' own apartments. RMR was measured by indirect calorimetry, and NIT was tested by giving the subjects an oral fluid test meal, then measuring metabolic rate again one hour later. Body composition was measured anthropometrically and FFM was calculated. Energy intake was calculated from a five-day record of weighed food. BMR was calculated using four different prediction equations and compared with measured RMR. Results: RMR was 1,174 kcal/d (29.3 kcal/kg FFM/d). The variation in RMR was significantly related to FFM ($p<0.0001$). Energy intake was 1,474 kcal/d, (36.5 kcal/kg FFM/d). The energy intake/RMR ratio, was 1.27, and NIT was 15% (0-33%). NIT was not correlated to any of the parameters tested. The equation of Harris & Benedict underestimated BMR by 4%; the WHO/FAO overestimated BMR by 7%; Schofield and an estimate of 20 kcal/kg/d did not significantly differ from the measured mean. Conclusion: RMR was closely correlated to FFM. Variations in NIT could not be explained by any tested parameters. Predicted BMR differed from measured RMR by less than 8% in all methods, but individual variations were large.

Key words: Elderly, nursing home, resting metabolic rate, energy intake, nutrient induced thermogenesis, body composition, fat free mass, BMR prediction equations.

Introduction

It has been shown that the resting metabolic rate (RMR) decreases with age in healthy elderly subjects (1-3). Total energy expenditure (TEE) also decreases, mainly due to a lower physical activity level (4). Many people gain weight during middle age, but a weight reduction can be seen in old age (5,6). The decreasing RMR in the elderly is considered a result of decreasing fat free mass (FFM) (7), but it does not fully explain the lower RMR in the elderly (1,3).

Weight loss and malnutrition are common in elderly people suffering from chronic diseases. This has raised the question of whether an elevated RMR may contribute to the development of this condition. Studies including patients with different chronic diseases have shown inconclusive results (8-26).

The nutrient induced thermogenesis (NIT) amounts to approximately 10 % of the total daily energy expenditure in healthy adults. In healthy elderly men it has been shown that the NIT was lower than in young men (27), but in one study this difference disappeared after adjustment for body composition (2). In women, no difference in NIT has been found between the young and elderly (28,2).

Aim of the study

- To investigate RMR and NIT in elderly people with multiple diagnoses in stable condition, living in a nursing home.
- To test if RMR and NIT correlate with age, body composition, energy intake, and activities of daily living (ADL).
- To test if energy intake was adequate in these patients compared to measured RMR.
- To test whether commonly used methods to predict basal metabolic rate in the elderly would be acceptable to use in this group as compared to measured RMR.

Material and methods

The study was performed during 2000 in elderly residents with multiple diagnoses living in a nursing home in Sundbyberg, a suburb of Stockholm, Sweden. The setting was a general nursing home where the residents had complex combinations of chronic diseases resulting in functional impairments with accompanying need of functional support and nursing care. After giving informed consent (from relatives when needed) all residents underwent a clinical examination by a geriatrician and were screened for baseline measurements. The patient characteristics are described in table 1.

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Table 1
Patients characteristics. ADL (activities of daily living) is expressed as median and range, all other variables as mean, SD and range. RMR = resting metabolic rate, BMI = body mass index. KATZ = index of functional ability in activities of daily living, where 0 = totally independent, and 12 = totally dependent

	Females with reliable results of RMR	**All females**	**Males with reliable results of RMR**	**All males**
Number of residents	33	60	8	14
Age (years)	84.3±7.5 (67-102)	85.6±6.8 (67-102)	81.6±7.4 (73-96)	81.6±6.9 (73-96)
Body weight (kg)	60.0±16 (33.1-95.0)	57.7±15 (33.1-95.0)	69.4±7.3 (57.1-79.3)	71.4±10.2 (54.1-92.6)
Fat free mass (kg)	40.9±7.9 (26.2-55.9)	40.6±8.0 (26.2-56.5)	53.3±4.2 (45.8-59.4)	54.5±5.9 (44.8-66.5)
Fat free mass (%)	70±7 (55-83)	70±6 (55-83)	77±3 (72-82)	77±4 (68-83)
Fat mass (kg)	18.9±8.7 (6.9-39.2)	18.4±8.2 (6.9-39.2)	15.5±3.1 (11.3-19.2)	16.6±5.0 (9.3-29.8)
Fat mass (%)	30±7 (17-42)	30±6 (17-42)	22±3 (18-27)	23±4 (17-32)
Height (cm)	157±7.2 (137-169)	156±6.5 (137-169)	172±5.0 (165-179)	172±5.0 (165-184)
BMI (kg/m^2)	24.3±6.7 (14.6-42.2)	23.9±6.0 (14.6-42.2)	23.9±3.0 (18.4-27.4)	24.2±3.0 (18.4-27.9)
ADL (Katz-index)	3 (0-11)	4 (0-11)	5.5 (0-10)	5 (0-10)

Resting metabolic rate

Resting metabolic rate (RMR) was measured by indirect calorimetry, using a MBM-200 Delta Trac II metabolic monitor (DATEX, Engström, Finland). Calibration by ethanol combustion was done before the study by the manufacturer. The calibration was validated every morning using a test gas of known composition provided by the supplier.

The subjects were asked to remain in bed in their own apartments on the morning of testing until the measurements began. They had been fasting since midnight. Early morning medications were given with water. Medications that were normally taken with breakfast were often given with the test meal (see below).

Measurements began between 7 am and 9.30 am. The first three minutes of measuring were not included in the results; during this time the subjects could calm down and get used to the ventilated hood that was placed over their head and shoulders. The supplier of the Delta Trac monitor recommended five minutes, but most individuals had a stable breathing after 3 minutes. We wanted to make the procedure as short as possible, since many of these very old people found the procedure uncomfortable. Measurements were continued for 10 minutes with stable breathing. The results were extrapolated to kcal/24 hours.

RMR was measured in a total of 81 individuals (61 females and 20 males). This included all residents who lived in the nursing home during the time of the study, except for two residents where measurements were impossible to perform because of severe dementia. Six males and one female were excluded from all analyses, either because they died shortly after RMR had been measured, and no other examinations had been made, or their breathing was so irregular that no estimation of RMR could be made, leaving 74 individuals for the initial analysis.

Another five females were excluded from analysis of RMR due to ongoing infection (1), obviously not fasting (2), irregular breathing (1) and unrealistic measured RMR (1).

We experienced several practical problems in performing measurements of RMR in the elderly residents, and thus decided that the following criteria should be fulfilled in order to include the results in the final analysis:

The resident should:
- be fasting since midnight
- not have risen before measurements began
- not talk during measurement
- not sleep heavily during the procedure
- have regular breathing
- have measurements with stable breathing for at least ten minutes
- not eat or rise between the measurements (except to void)
- drink all 200 ml of the liquid test meal

Because of problems fulfilling the criteria listed above, RMR measurements were accepted only for 41/81 residents (51 %), 8 males and 33 females. Comparing the results of the whole group with those results acceptable according to the chosen criteria showed little difference, but we present results only for those fulfilling the stringent criteria.

Test meal - NIT

Directly after the measurement was completed the subjects were given 200 ml of an oral fluid supplement, (Additene, NOVARTIS NUTRITION). The total energy content was 200 kcal (34% of energy from protein, 57% from carbohydrates, 9%

from fat). The high protein content was chosen because protein has the highest stimulating effect on the NIT. The subjects were then asked to remain in bed until the next measurement, which was done one hour (± 10 minutes) after they had finished the test meal. The residents were allowed to rise to void, except just before the second measurement. According to the criteria listed above, NIT-measurements were acceptable in 23/81 residents (28%), 19 women and 4 men. NIT was calculated as postprandial rise of RMR at one hour after ingestion. This method does not reflect total NIT of the test meal, but it constitutes an estimate of NIT at one point in time. It was not possible to make repeated measurements over several hours in these elderly, frail subjects, which is already shown by the fact that it was only possible to measure NIT under stringent conditions in 23 of the individuals. The alternative would have been to perform the study in a laboratory or clinic, but this was not possible for practical and ethical reasons considering transportation in the fasting state, etc.

Prediction of basal metabolic rate

Predicted basal metabolic rate (BMR) was calculated according to the equations by Harris Benedict, Schofield and the WHO (29-31). We also compared the results with a standard calculation of 20 kcal/kg/day, since this simple method is used to estimate BMR in clinical settings in Sweden.

Energy intake

Energy intake was determined by weighed food intake analysis during five consecutive week-days carried out by a nutritionist with the assistance of the personnel at the nursing home. All hot meals and the leftovers were weighed to the nearest gram using a digital kitchen scale (PHILIPS HR 2385) with a resolution of one gram within the interval of 0-5 kg. Drinks and breakfast dishes such as porridge and yoghurt were weighed, but weights of sandwiches were standardized and referred to as "normal" or "small". Energy intake was recorded Monday through Friday the week before the energy expenditure was measured. It was not practical to include weekends in the weighed food record, as there were fewer personnel working in the nursing home then.

Body composition

The patients were weighed, dressed in underwear, to the nearest 0.1 kg on a digital chair scale (UMEDICO SV-600, Rosersberg, Sweden). For most residents, height was measured to the nearest centimeter in the standing position using a stadiometer. In those 10 residents not able to stand even with support (due to e.g. contracures of muscles and joints in the extremities) height was approximated by adding the measurements of head-shoulder, shoulder-hip, hip-knee, and knee-heel. In a few cases the latest known height was used.

All height measurements were performed by the same investigator. The body mass index (BMI) was calculated by dividing the body weight (kg) by height^2 (m).

Four skin folds were measured using a Harpenden caliper (BRITISH INDICATORS LTD, Bedfordshire, UK) (32) over biceps, triceps, subscapular and crista iliaca in the left side using the mean of three measurements to the nearest 0.1 mm from each location. Body density and fat mass were calculated from the sum of these four skin folds using prediction equations (33,34). Fat free mass (FFM) was calculated as body weight minus fat mass.

Activities of daily living

Functional ability in Activities of Daily Living (ADL) was examined according to the Katz Index (35) by a physiotherapist, who interviewed the nursing home personnel. The Katz index tests the level of functional independence in six categories: bathing, dressing, toileting, transferring, continence, and feeding. To facilitate statistical analysis each category was assessed on a three-level scale (0 = independent, 1 = human aid, 2 = totally dependent), with a total score of 0-12, where 0 represents total independence (36,37).

Statistical methods

Calculations were carried out using SAS v.8, (SAS INSTITUTE, Cary; USA). Graphs were designed in Mathlab v.6, and Microsoft Excel. The univariate and multivariate analysis of explaining factors for RMR and NIT was performed using a general linear model. The regression was done stepwise backwards. Fit was examined by standard residual plots.

Results

Due to the low number of males the results for males are only shown for RMR and energy intake. All other results presented are for females with acceptable results of RMR (n=33) or NIT (n=19). Energy intake is only presented for 29 of the 33 females due to acute illness in four patients, resulting in a very low intake during the time of dietary assessment.

Figure 1 shows body composition as total body weight and its components, fat free mass (FFM) and fat mass in the individuals, sorted from lowest to highest FFM.

Table 2 shows RMR and energy intake. Mean RMR for females was 1,174 kcal/d, (29.3 kcal/kg FFM/d). RMR/kg FFM was higher in those with a low FFM (p=0.003). Mean energy intake was 1,474 kcal/d, (36.5 kcal/kg FFM/d). RMR and energy intake were significantly correlated (p=0.0012). The energy intake/RMR ratio, was 1.27, which represents an estimate of the physical activity level (PAL).

In a multivariate model for analysis of RMR the factors age, height, FFM, fat mass and activities of daily living (ADL, Katz score), were tested. Results showed that RMR increased significantly with increased FFM ($p < 0.0001$). RMR was also shown to be inversely related to age, but this finding did not reach significance (p=0.087). The variables FFM and age explained together about 52% of the variation in RMR (R^2=0.52). Sergi et al found an inverse correlation between KATZ and FFM (37), but we could not find such a correlation (p=0.164).

Figure 1
Fat free mass (FFM) and fat mass as part of total body weight in 33 females

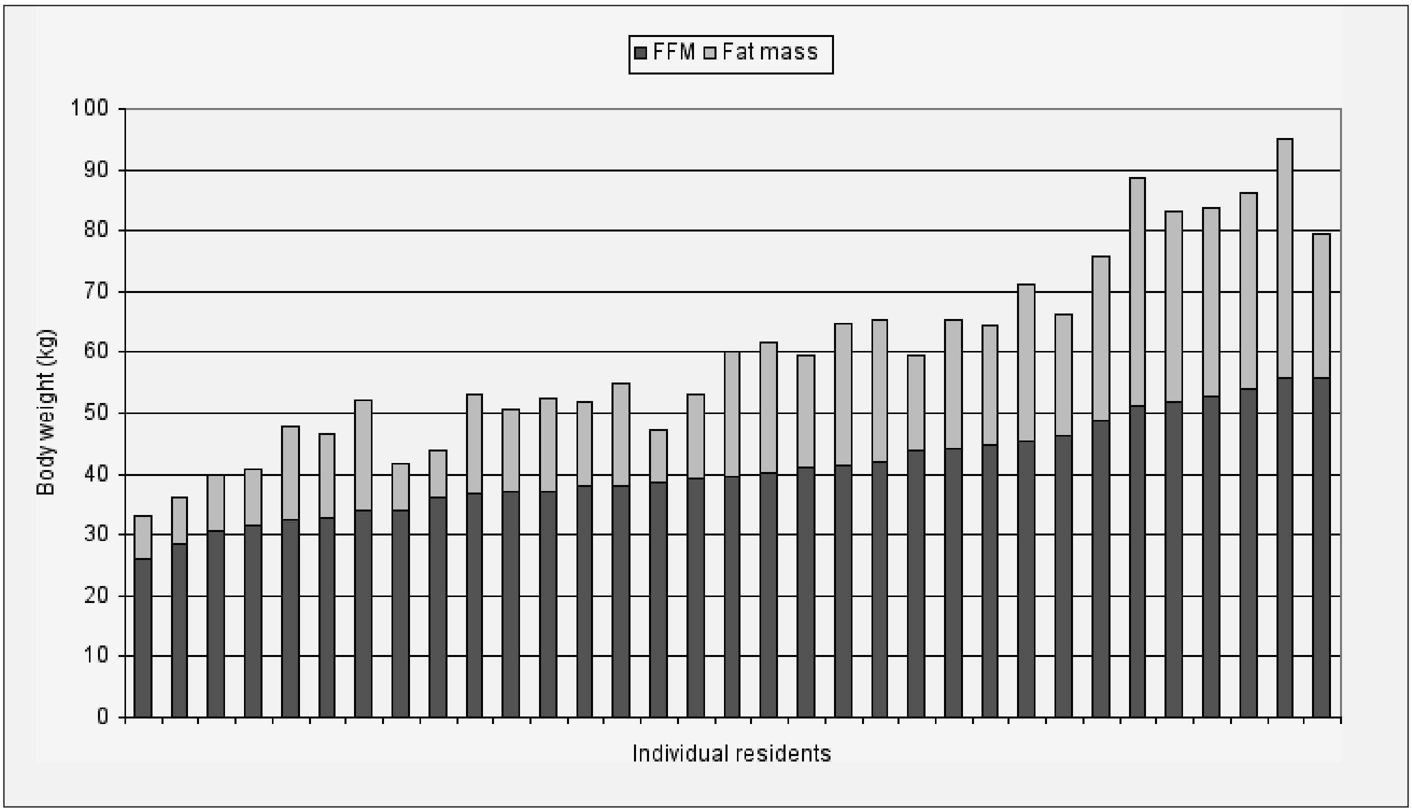

Figure 2
Nutrient induced thermogenesis (NIT).Postprandial rise of metabolic rate at one hour after ingesting a test meal 19 females in per cent of measured resting metabolic rate (RMR)

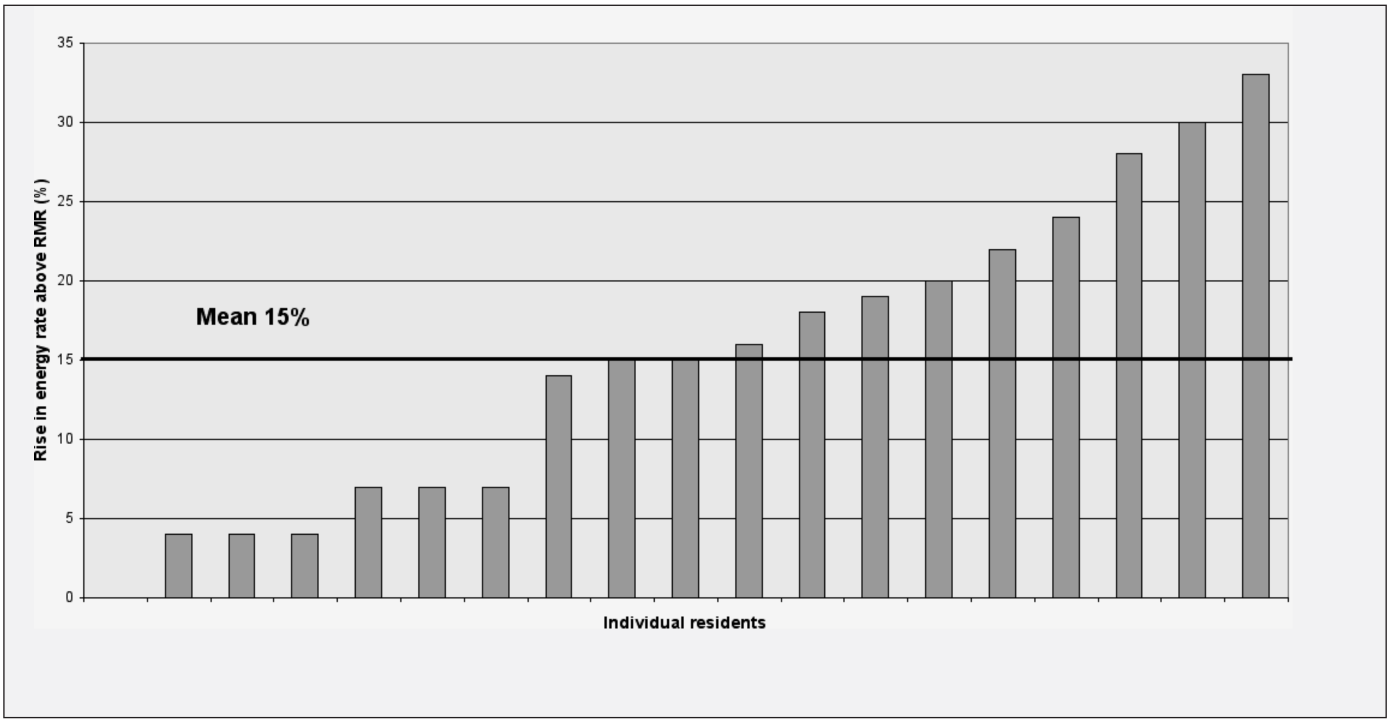

Figure 3
Mean and limits of confidence of differences between predicted BMR and measured RMR by four different methods. BMR = basic metabolic rate, RMR = resting metabolic rate

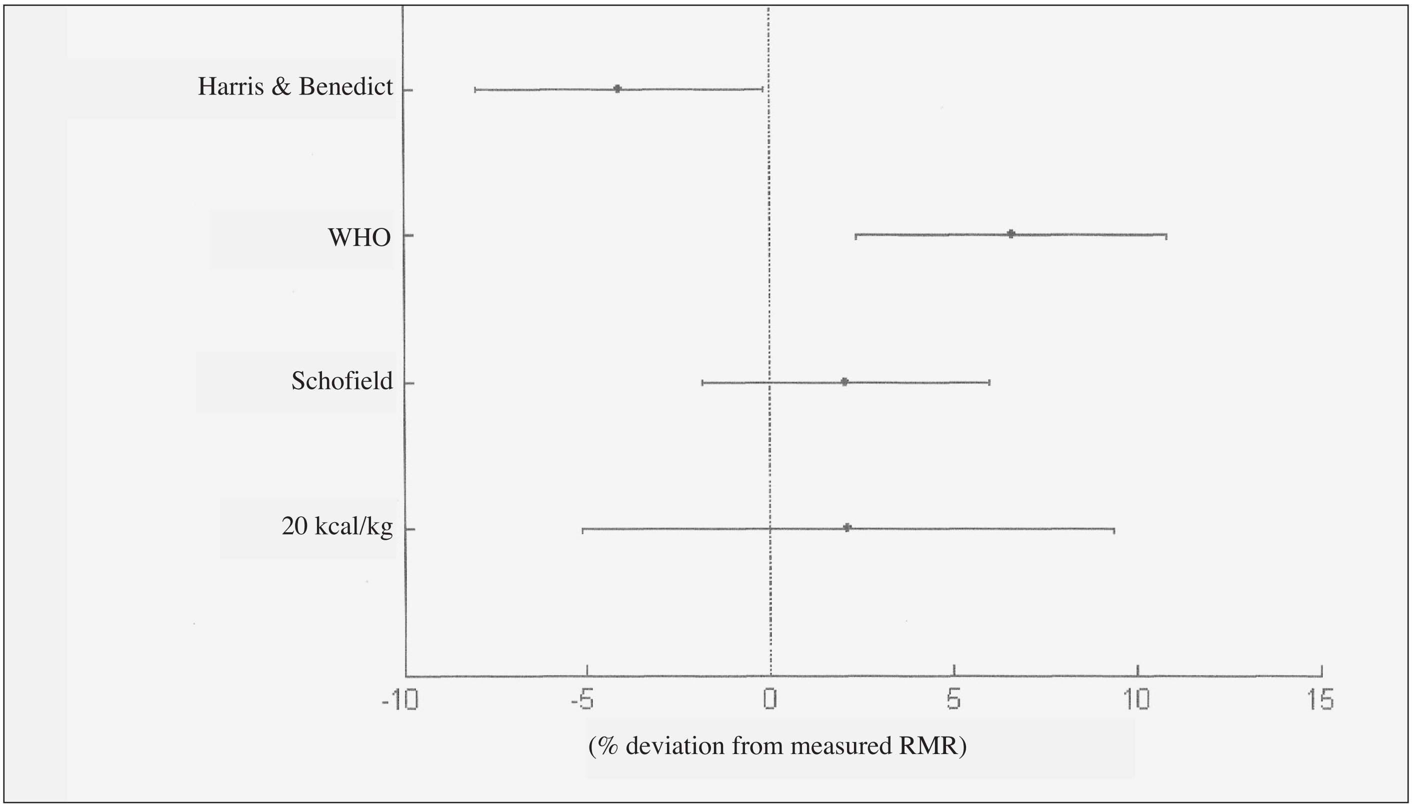

Table 2
Resting metabolic rate (RMR) and energy intake. All results are expressed as mean, SD and range. BW = body weight, FFM = fat free mass, PAL = physical ectivity level

	Females with reliable results of RMR	**All females**	**Males with reliable results of RMR**	**All males**
Number of residents	33	55	8	14
RMR (kcal/d)	1174±175 (810-1560)	1161±189 (810-1630)	1419±143 (1220-1570)	1474±173 (1220-1730)
RMR/body weight (kcal/kg/d)	20.4±4.3 (15.1-29.6)	20.7±4.3 (14.7-29.6)	20.7±3.1 (16.5-25.4)	20.9±3.1 (16.5-27.0)
RMR/fat free mass (kcal/kg FFM/d)	29.3±4.2 (22.0-39.2)	29.5±4.6 (20.4-40.5)	26.7±3.2 (22.2-31.6)	27.2±3.1 (22.2-32.6)
Energy intake (kcal/d)	1474±255 (1062-1939)	1476±223 (1037-1939)	1653±149 (1486-1895)	1764±228 (1486-2221)
Energy intake (kcal/kg BW/d)	25.3±6.0 (16-39)	25.9±5.9 (16-40)	24.0±2.6 (20-28)	24.8±2.8 (20-30)
Energy intake (kcal/kg FFM/d)	36.5±6.2 (26-49)	37.2±6.4 (26-51)	31.1±2.5 (27-34)	32.4±3.0 (27-37)
Energy intake/RMR (estimate of PAL)	1.27±0.20 (0.97-1.72)	1.30±0.20 (0.97-1.76)	1.19±0.13 (1.00-1.35)	1.21±0.11 (1.00-1.35)

Figure 2 shows the NIT at 1 hour after ingesting a test meal. Mean NIT was 15 % above RMR, varying from 0–33 %. Univariate analysis showed that none of the factors – age, height, FFM, fat mass or ADL - could explain the variation in NIT. We also tried to relate NIT to the protein load of the test meal expressed per kg FFM of the subjects, as well as to the energy content of the test meal as part of RMR, but this gave no further information.

Figure 3 shows a comparison between measured RMR and predicted basal metabolic rate (BMR) calculated by four different methods. It can be seen that the equation of Harris Benedict (HB) underestimated BMR by 4% on average, while the WHO/FAO-equation overestimated BMR by 7%. Both differences were statistically significant. Schofield and an estimate of BMR of 20 kcal/kg body weight, however, were not statistically different from the measured mean RMR. The maximum individual variation between measured and calculated RMR was lowest for HB, and highest when using an estimate of 20 kcal/kg/day, where the largest difference between measured RMR and predicted BMR was 33%.

Discussion

The mean RMR for these elderly, diseased women was 1,174 kcal/day. Other studies have found that mean RMR varied from 1,147 to 1,472 kcal/day in elderly women (1,2,28,38,39).

In these studies the women were free living, considered healthy, and much younger than in the present study. One study of free living females aged 91-96 found a mean RMR of 1,282 kcal/day (40).

In most studies RMR was measured for 30-45 minutes. In our study, however, RMR was only measured for 10 minutes, since we wanted to make the procedure as short as possible for these elderly, disabled people. On the other hand, we required stable measurements and used strict criteria for exclusion in the analysis, which can compensate for the short measuring period.

The RMR-results were extrapolated to 24 hours. This generates an estimate, since it is not known how RMR varies during the day in the elderly. Fredrix et al (38) concluded that sleeping energy expenditure is 7 % lower than RMR in healthy elderly people with an average age of 65 years. We have previously observed a considerable diurnal variation in RMR in elderly, multidiseased females where RMR was significantly higher during the day compared to early morning (manuscript in preparation). However, in this study measurements during the day could include NIT to some degree, since the subjects had only been fasting for 2-4 hours before each recording. Physical activity was very low in most of the subjects, so this would not have influenced RMR to any degree.

There was a great heterogeneity among the female residents: The age range was from 67-102 years, body weight varied by a factor of 3 (33–95 kg), BMI by a factor of 3 (14-42), FFM by a factor of 2 (26-56 kg) and fat mass with a factor of 5 (7-39 kg). RMR varied with a factor of 2, also present after correction for differences in body weight (15-30 kcal/kg/d) and body composition (22-39 kcal/kg FFM/d).

The RMR/FFM ratio was not constant, but increased with decreasing FFM. In elderly malnourished subjects the RMR/FFM ratio is often elevated, which can be interpreted as a state of hypermetabolism (22). This "ratio method" has been criticized for creating false differences or lack of differences between groups varying in FFM (41,42). Sergi et al used analysis of covariance to normalise RMR for FFM as recommended by Toth and Poehlman (42), which instead indicated a state of hypometabolism in the malnourished elderly (37). Interestingly, Schneider et al showed an increased RMR/FFM ratio in the malnourished elderly, but in the middle-aged malnourished control group the RMR/FFM ratio was similar to that in normal weight subjects (43). The statistical method chosen to normalize for body size should be chosen with care, considering the purpose of the analysis (44). In this study the simple ratio method was chosen, since the aim of the study was not to compare RMR between groups. We cannot exclude the possibility that the elevated RMR in those with a low FFM is a result of the normalization procedure. On the other hand, in a person with a diminished muscle mass, it is possible that the visceral organs would contribute more to the resting metabolic rate, with a higher RMR/FFM as a consequence.

There was also a great variation in energy intake. In relation to RMR intake was low and the average energy intake/RMR ratio was only 1.27 (1.19 in males). A ratio above 1.0 represents the energy available for NIT and physical activity. Bed- or chair-bound subjects have a ratio about 1.2 (45). In studies on energy intake a low ratio is often considered indicative of underreporting. In our study such underreporting is possible, but it is not likely that this would fully explain the low energy intake in relation to RMR. In fact, many of the elderly ladies had a low food intake, and said at every meal "please, don't give me so much food". The weighed food technique we used is probably an accurate estimate of the habitual energy intake in a group of residents in a nursing home. The low energy intake/RMR-ratio in some individuals raises the question of whether they were in negative energy balance and what should be done to maintain or improve their nutritional status. However, we did not observe any difference between those with a low or high ratio, respectively, regarding body weight development in the time following our study. In the majority of the residents of this nursing home the physical activity was very low, with 9 out of 33 subjects (27 %) being practically chair bound.

In some studies on NIT the same test meal size has been used for all participants (2, 27), while other studies have adjusted the caloric content of the test meal to measured RMR (14, 17). One may also argue that the energy-load should be proportional to the body weight of the patients studied. The issue of energy-load to elicit NIT is complicated by the fact that one must combine both i) amount of energy and ii) type of energy-containing substrate (since proteins produces much higher NIT than carbohydrates and fats produce almost no NIT) in order to choose the ideal normalized NIT-load. Since such information is not availiable, we chose to use a standardized, high-protein dose (a total of 200 kcal load where 34 % of the energy came from protein) aiming at stimulating NIT as much as possible.

To test if the large observed variation in NIT could be explained by the standardized energy load we tried to normalize the energy content of the test meal to RMR, but neither this, nor normalizing the protein load to body weight or LBM gave any correlation with NIT.

It is possible that there is an inter-individual variation of NIT response in time after ingesting a meal, but as mentioned in the introduction, it was not possible to make continuous measurements of the metabolic rate.

Prediction of RMR by any of the four used methods agrees rather well with the measured results on a group level. The average variation was less than 8 % in all methods. Other studies have concluded that the equations by Harris & Benedict (HB) and Schofield underestimates RMR in elderly males (38,46). In elderly females HB and the WHO/FAO overestimated RMR by 3 % and 9 % respectively (47). In our study HB underestimated RMR by 4%, and WHO/FAO overestimated RMR by 7%. The Schofield equation gave the most accurate prediction of the measured RMR. It is interesting to note that a simple estimate of 20 kcal/kg body weight/d gave a mean RMR that was the closest to that measured. This method is used in the clinical setting, however, it also showed the largest individual variation (± 33%), which means that such an estimate, in many cases, will not be close to the true individual RMR.

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