Title	A new equation to estimate basal energy expenditure of patients with diabetes
Author(s)	Ikeda, Kaori; Fujimoto, Shimpei; Goto, Masashi; Yamada, Chizumi; Hamasaki, Akihiro; Ida, Megumi; Nagashima, Kazuaki; Shide, Kenichiro; Kawamura, Takashi; Inagaki, Nobuya
Citation	Clinical nutrition (2013), 32(5): 777-782
Issue Date	2013-10
URL	http://hdl.handle.net/2433/178761
Right	© 2012 Elsevier Ltd and European Society for Clinical Nutrition and Metabolism.
Type	Journal Article
Textversion	author

A new equation to estimate basal energy expenditure of patients with diabetes.

Kaori Ikeda[1], Shimpei Fujimoto[1, 2], Masashi Goto[3], Chizumi Yamada[1], Akihiro Hamasaki[1], Megumi Ida[4], Kazuaki Nagashima[1], Kenichiro Shide[4]; Takashi Kawamura[3], Nobuya Inagaki[1]

[1] Department of Diabetes and Clinical Nutrition, Graduate School of Medicine, Kyoto University

[2]Department of Endocrinology, Metabolism and Nephrology, Kochi Medical School

[3] Kyoto University Health Service

[4]Department of Metabolism and Clinical Nutrition, Kyoto University Hospital

E-mail addresses: kaikeda@metab.kuhp.kyoto-u.ac.jp (K. Ikeda), fujimoto@kochi-u.ac.jp (S. Fujimoto), goto@msa.biglobe.ne.jp (M. Goto), chizumi-y@nifty.com (C. Yamada), hamasaki@metab.kuhp.kyoto-u.ac.jp (A. Hamasaki), idamegu@kuhp.kyoto-u.ac.jp (M. Ida), nagasima@metab.kuhp.kyoto-u.ac.jp (K. Nagashima), shide@kuhp.kyoto-u.ac.jp (K. Shide), kawax@kuhp.kyoto-u.ac.jp (T. Kawamura)

Short title: new equation to estimate basal energy expenditure

Corresponding Author:
Nobuya Inagaki, MD, PhD
Department of Diabetes and Clinical Nutrition
Graduate School of Medicine, Kyoto University
Address: 54 Shogoin Kawahara-cho, Sakyo-ku, Kyoto 606-8507, Japan
Tel: +81-75-751-3562
Fax: +81-75-771-6601-
E-mail: inagaki@metab.kuhp.kyoto-u.ac.jp

A part of this study was presented in abstract form at the annual meeting of American Diabetes Association, New Orleans, Louisiana, 5-9 June 2009.

ABSTRACT(<200 words)

Background & Aims

Predictive equations for basal energy expenditure (BEE) derived from Caucasians tend to overestimate BEE in non-Caucasians. The aim of this study was to develop a more suitable method to estimate BEE in Japanese patients with diabetes using indices readily measured in clinical practice.

Methods

BEE was measured by indirect calorimetry under a strict basal condition in 68 Japanese patients with type 1 or type 2 diabetes. The best fitting equation was investigated by multiple regression analysis using of age, sex, and anthropometric indices. The resultant new equation was tested in a separate group of 60 Japanese patients with type 1 or type 2 diabetes, and the accuracy compared with existing equations.

Results

The best-fit equation was BEE[kcal/day] = 10×(body weight)[kg] – 3×(age)[y] + 125(if male) + 750. Adjusted coefficient of determination was 81.0%. Root mean squared errors and accurate prediction in the validation set were 103 kcal/day and 78% for the new equation; 184 and 50 for Harris-Benedict; 209 and 38 for Oxford; 205 and 42 for Liu; and 140 and 63 for

Ganpule.

Conclusions

This new equation is simpler and estimates BEE more accurately in Japanese patients with diabetes than the presently used equations do.

Keywords: basal metabolic rate; resting metabolic rate; indirect calorimetry; prediction equation; diabetes; medical nutrition therapy

1. Introduction

Diet is the most fundamental and initial treatment for all patients with diabetes, and poor dietary management alone predicts poor subsequent glycemic control (1). Estimation of daily energy expenditure for each patient is necessary for effective individualized diabetic meal planning. Resting energy expenditure (REE) or basal energy expenditure (BEE) is defined as the energy expended to maintain minimal metabolic activities, and is the main component of total daily energy expenditure. To estimate daily energy expenditure, REE or BEE is multiplied by a number specific to the various daily activities.

In healthy subjects, 65 to 90% of inter-individual variation in REE is explained by fat-free mass (FFM) (2). In patients with diabetes, FFM is also the main factor in REE and BEE (3-5), and there is no difference in FFM-adjusted REE between mildly hyperglycemic patients and controls (6). In clinical practice, BEE or FFM are not usually available. Equations factoring body weight, height, age and sex are widely used for clinical estimation of the daily energy requirement of patients with diabetes (7). However, there has been little investigation of the comparative validity of these equations.

The existing predictive equations derived from Caucasians are unevenly applied to non-Caucasians, tending to overestimate energy expenditure (8-11). This accords with the recent finding from the basal metabolic rate database that BEE is higher in Caucasians than in non-Caucasians (12). However, REE is similar in Asians and Caucasians after adjustment for FFM, and BEE in Indians and Australians is similar after adjustment for FFM and fat mass (13, 14). To date, there are few equations to estimate energy expenditure specifically in Asian populations (10, 15).

Differences in the measurement technique of REE can cause biases (12). In most studies evaluating energy expenditure, REE has been used rather than BEE. However, REE is defined less rigorously than BEE and is influenced by physical and psychological stress and ambient and body temperature (16-18). Since BEE is measured early in the morning before the subject begins any physical activity and at least 10 hours after ingestion of any food, drink, or nicotine, it remains remarkably constant on a daily basis (16, 18).

In the present study, by measuring BEE under strict conditions, we developed a new equation for estimation of BEE in Japanese patients with diabetes for use in a clinical setting.

2. Patients, materials and methods

Patients

Japanese patients with type 1 or type 2 diabetes admitted to the Department of Diabetes and Clinical Nutrition, Kyoto University Hospital, Kyoto, Japan for diabetes self-management education during the period of December 2007 through September 2009 were recruited for derivation study. Written, informed consent was obtained from all participants. During hospital stay, the participants had a prescribed diet with or without medications including oral hypoglycemic agents and insulin according to the treatment guide for diabetes of the Japan Diabetes Society (19). Their physical activity was not restricted, but they did not engage in vigorous exercise. Participants were screened by medical history, physical examination, and laboratory testing to assure the absence of hepatic, pulmonary, thyroid, cardiac and renal dysfunction, macroalbuminuria, inflammatory diseases, and malignant tumors. Those who took steroids or beta blockers or had physical disabilities were excluded. The study protocol was approved by Kyoto University Graduate School and Faculty of Medicine, Ethics Committee.

Indirect calorimetry

Basal energy expenditure (BEE) was measured in the morning under glycemic control with prescribed diet (29.1±2.5 kcal/kg of standard body weight per day consisting of 52% carbohydrate, 20% protein, and 28% fat in energy component) and with medications when needed. Standard body weight (kg) was calculated by multiplying 22 (kg/m^2) by square of height (m). Whole-body oxygen consumption (VO_2) and carbon dioxide production (VCO_2) was measured for more than 10 minutes with indirect calorimetry (AE300S, Minato Medical Science, Osaka, Japan) by one investigator (KI) at the bedside of each patient under the strict condition described previously (5, 16, 17). Briefly, an afebrile patient in a post-absorptive state after an overnight fast (14 hours) with <180 mg/dL capillary plasma glucose remained in a supine position after waking on the bed in the ward without smoking or taking caffeine, and the measurements were performed at room temperature between 22ºC and 27ºC. After discarding the initial 5 minutes of recording, we took 5-minutes of data, in accord with the steady state definition (17), during which the coefficient of variation for VO_2 per minute and VCO_2 per minute was achieved $\leq$10%, and applied them to the Weir formula with 24-hour urinary urea nitrogen (20).

Anthropometry and body composition

Height was measured on the day of admission. Body weight, skinfold thickness, and waist circumference were measured immediately after the measurement of BEE by one investigator (KI). Triceps-skinfold thickness (TSF) and mid-upper arm circumference (MAC) were measured in the non-dominant arm with the elbow bent at 90°. The physical markers were measured at least twice, and their respective mean values expressed according to Japanese standard method (21). Arm muscle circumference (AMC) and arm muscle area (AMA) were calculated; AMC [cm] = MAC [cm] − π × TSF [mm] /10, AMA [cm^2] = (AMC [cm])^2 / 4π. Waist circumference was measured at the mid-point between the lowest rib and the iliac crest in a standing position at the end of gentle expiration keeping the measuring tape horizontal and just fitted to the skin. Hip circumference was measured at the widest part of the hip while standing. FFM and fat mass were measured by dual energy X-ray absorptiometry scanner (Discovery, Hologic, Bedford, MA, USA) within 3 days before and after measurement of BEE.

Other measurements

Glycated hemoglobin was measured by use of HPLC (ADAMS™ A1C HA8180, Arcray, Kyoto, Japan) and expressed as a National Glycohemoglobin Standardization Program (NGSP) equivalent value [%] calculated by the formula HbA1c [%] = HbA1c [Japan Diabetes Society (JDS)] [%] + 0.4 [%], which considers the relational expression of HbA1c (JDS) measured by the previous Japanese standard substance and measurement methods and

HbA1c (NGSP) (22). Capillary glucose before each meal was measured by glucose meter (One Touch Ultra™, Johnson & Johnson, New Brunswick, NJ, USA) and expressed as capillary plasma glucose (PG). As a parameter of glycemic control, mean preprandial PG for three consecutive days before the measurement of BEE and fasting PG (FPG) just before the measurement of BEE are shown.

Testing the new equation

A separate data set of Japanese patients with type 1 or type 2 diabetes admitted to the same department for the same purpose during the period of June 2005 through December 2007 was drawn from the medical records for validation study. Inclusion/exclusion criteria and dietary condition during hospital stay were similar to that of the derivation sample.

Whole-body VO_2 and VCO_2 was measured after an overnight fast (14-16 hours) for more than 15 minutes with the same calorimetry by one investigator (MI) on the same condition. Each patient was conveyed from their ward to the examination room by a healthcare staff member in a wheel chair and they rested in bed in a supine position for 30 minutes before the measurement of BEE. BEE was calculated from VO_2 and VCO_2 by use of Elwyn formula (BEE [kcal/day] = $3.581 \times VO_2$ [L/day] + $1.448 \times VCO_2$ [L/day] – 32.4) (16). Body weight was measured on the day of calorimetry.

The protocol of this validation study was also approved by Kyoto University Graduate School and Faculty of Medicine, Ethics Committee.

Statistical analysis

Numerical data are summarized as means ± SDs. Categorical data were treated as dummy variables.

We first explored good estimators for FFM and fat mass in anthropometric indices, such as body weight, height, TSF, AMA, waist circumference and hip circumference, because FFM and fat mass are known as two major estimators of BEE. Correlations between these variables were evaluated by Pearson's correlation analysis. Multiple linear regression analysis was then performed to evaluate the contribution of anthropometric indices, age, and sex to FFM and fat mass. Next, a best-fit equation to estimate BEE from anthropometric indices, age, and sex was explored by multiple linear regression analysis with consideration of estimators of FFM and fat mass.

For testing the validity of our new equation and comparing it with existing prediction equations, we calculated measures of accuracy. The mean percentage difference between BEE estimated and measured (bias) was considered systematic error. The root mean squared error (RMSE) was considered to reflect each individual's error range unrelated to whether it was over or under estimation. The proportion of patients with BEE estimated within ±10% of BEE measured was considered another measure of accuracy (23).

Data were analyzed by use of Stata 11.0 (Stata Corporation, College Station, TX, USA). Statistical significance was set at $P<0.05$ (2-tailed).

3. Results

Data were obtained and analyzed in 68 patients, of which 7 had type 1 diabetes and 61 had type 2 diabetes. Mean glycated hemoglobin (HbA1c) on admission was as high as 10.5%, but mean fasting plasma glucose just before the measurement of BEE (FPG) was as low as 113.7 mg/dL due to the treatments during hospital stay (**Table 1**). Additional characteristics of patients in the derivation set and the results of measurement are shown in **Table 1**.

Body weight had the highest correlation with FFM (r = 0.90), followed by arm muscle area (AMA), height and hip circumference (r = 0.84, 0.75 and 0.73, respectively) (**Table 2**). Waist circumference had the highest correlation with fat mass (r = 0.91), followed by hip circumference, triceps-skinfold thickness (TSF) and body weight (r = 0.79, 0.78 and 0.75, respectively).

In regression analysis for FFM, we selected body weight, AMA, height and hip circumference as potent estimators together with other plausible estimators, age and sex. As both AMA and hip circumference were strongly correlated with body weight and AMA was also strongly correlated with hip circumference, to analyze these three variables separately, we used three sets of independent variables, (body weight, height, age and sex), (AMA, height, age and sex), and (hip circumference, height, age and sex). The regressions revealed that all four variables were significant estimators for FFM in the first analysis (model 1 in **Table 3**), that AMA and height were significant in the second analysis (model 2) and that hip circumference, height and sex were significant in the third analysis (model 3). The first four variables accounted for 95% of variation in FFM, the second two variables 84%, and the third three variables 87%. For fat mass, we selected another three sets of independent variables, (waist circumference, age and sex), (hip circumference ,TSF, age and sex) and (body weight, TSF, age and sex) because waist circumference had a strong correlation with hip circumference, TSF and body weight, and hip circumference also had a strong correlation with body weight. In the first analysis, only waist circumference and sex were significant estimators for fat mass, accounting for 86% of fat mass (model 4). In the second analysis, hip circumference, TSF and age were significant, accounting for 84% of fat mass (model 5). In the third analysis, body weight, TSF, age and sex were significant, accounting for 87% of fat mass (model 6).

We performed regression analysis to determine BEE with the most influential estimators (FFM and fat mass) and plausible additional estimators (age and sex), which together explained 81% of the variation (model 7 in **Table 3**). We then performed backward stepwise estimation, using three sets of variables, (significant variables in model 1 and 6; body weight, height, TSF, age and sex), (significant variables in model 2 and 4 plus age;

AMA, height, waist, sex and age), and (significant variables in model 3 and 5; hip circumference, height, TSF, age and sex). The best fitting regression for BEE consisted of body weight, age and sex in the first analysis (model 8), height, waist, age and sex in the second analysis (model 9), and hip circumference, height, TSF and sex in the third analysis (model 10). The adjusted coefficient of determination in model 8 was 81%, which was larger than the 73% in model 9 and the 77% in model 10. The detailed results of model 8 are shown in **Table 4**.

We then simplified the resultant equation of model 8 to make it easy to use in clinical practice.

BEE = 10 × body weight − 3 × age + 125 (if male) + 750.

[BEE (kcal/day), body weight (kg), age (year)]

The bias of this equation in the derivation set was – 1.2 ± 6.4%; RMSE was 94 kcal/day; accurate estimation was 91%.

We then tested this new equation in a separate validation data set comparing it with existing equations **(Table 5)**. Characteristics of patients in the validation set are shown in **Table 6**. The ratio of patients with type 1 and 2 diabetes was almost the same as in the derivation set. Mean age was similar to that in the derivation set, but there were more obese people in the validation set. FPG and PPPG, which represent the glycemic levels around the time of measurement of BEE, were higher, but HbA1c on admission was lower than that in the derivation set. Mean duration of diabetes was similar to that in the derivation set. Prescribed diet was almost the same as in the derivation set, but treatment with insulin was more common in the derivation set. The bias of the new equation was 4.8 ± 7.7%, RMSE was 103 kcal/day, and the percent of patients estimated within 10% of measured value was 78 %. The new equation had better validity than Harris and Benedict equation, Oxford equation, or the Liu equation and Ganpule equation (**Table 7**).

4. Discussion

We report a new equation to estimate BEE in Japanese patients with diabetes with higher accuracy compared to existing equations. As in other BEE estimation equations, the main estimator was FFM and additional estimators were fat mass, age and sex (2-4, 24). Stepwise estimation analysis of the estimators of FFM and fat mass in the present study revealed that no other indices improved fitting of the equation for BEE except body weight, age and sex. Although anthropometric indices are good estimators for body composition and they improve predictability of certain equations for BEE (25, 26), they were not as effective as body weight in the present study. This accords with the finding that the standard error of the estimate of REE prediction by weight, height, sex and age was well within the range of the standard error of estimates from other FFM-derived prediction equations (27). Since ethnic difference in BEE is derived from differences in body composition (13), an ethnicity-specific constant term could more precisely estimates BEE (4, 12), but an ethnicity-specific coefficient of anthropometry is also valid.

We compared our new equation with existing equations such as Harris and Benedict, Oxford, Liu, and Ganpule because the Harris and Benedict equation is widely known in clinical practice in Japan, the Oxford equation was recently developed from a large number of subjects including many ethnicities, and the Liu equation and Ganpule equations were derived from Chinese and Japanese subjects, respectively (7, 10, 12, 15). The validation analysis revealed better validity of the new equation in Japanese patients with diabetes than any of the other equations.

BEE was measured under strictly controlled conditions in the present study. In addition, we confirmed the FPG of the patients to be <180 mg/dL just before the measurement of BEE, since BEE is unaffected by the glucose level when its value is <180 mg/dL (5, 6). As the mean FPG of patients in the derivation set was improved to 114 mg/dl just before the measurement of BEE due to the prescribed diet and medications during hospital stay, in contrast to the poor mean FPG level as high as 170 mg/dl just after admission, clinical application of this equation to patients with stable glycemic control is recommended.

There are potential weaknesses of the present study. First, only a small number of patients with type 1 diabetes was included. However, no difference in the value of BEE between patients with type 1 and type 2 diabetes has been described to date. In type 1 diabetes, the elevated energy expenditure is observed only during insulin deprivation, and it returns to normal level by insulin treatment (28). In type 2 diabetes, there is no difference in FFM-adjusted REE between mildly hyperglycemic patients and controls (6). Thus, when they are under treatment, BEE in both type 1 and type 2 diabetes patients can be assumed comparable to that in healthy people. In addition, our validation data set has more background in common with the derivation set than the general population of Japanese patients with diabetes. We also did not measure BEE of healthy Japanese for comparison. It remains to be established whether or not the difference in BEE between Japanese patients with diabetes and healthy Japanese is insignificant when FPG of patients are <180 mg/dL.

The values estimated from the proposed equation in the present study are well matched to the reference values for Japanese BEE (Dietary reference intakes) reported in healthy Japanese as values per body weight among different groups for age and sex (29). In addition, when mean BEE values were calculated by the proposed equation from mean body weight and age reported in other studies including healthy Japanese and Chinese, estimated BEE values were in good agreement with measured values (10, 15, 30).

We report a new equation using parameters readily available in clinical practice to estimate BEE of patients with diabetes in an Asian population. Further studies are required to in a wide range of populations to determine its usefulness in Asian clinical settings.

Statement of Authorship

The authors' responsibilities were as follows: KI, SF, MG, and TK designed research; KI, CY, AH, MI, KN and KS conducted research; KI, MG, and SF analyzed data; KI and SF wrote the paper; and NI supervised research. All authors read and approved the final manuscript.

Conflict of Interest & Acknowledgements

None of the authors had any conflict of interest.

This study was supported by a research grant from the Ministry of Health, Labour and Welfare of Japan and also by Kyoto University Global COE program "Center for Frontier Medicine".

The authors thank Masayuki Yokode from Kyoto University Hospital Translational Research Center Department of Clinical Innovative Medicine for his general assistance in conducting this research.

REFERENCES

1) American Diabetes Association. Nutrition recommendations and interventions for diabetes: a position statement of the American Diabetes Association. Diabetes Care 2008; 31 (Suppl 1): S61-78.

2) Cunningham J J. Body composition as a determinant of energy expenditure: a synthetic review and a proposed general prediction equation. Am J Clin Nutr 1991; 54: 963-9.

3) Bitz C, Toubro S, Larsen T M, Harder H, Rennie K L, Jebb S A, Astrup A. Increased 24-h energy expenditure in type 2 diabetes. Diabetes Care 2004; 27: 2416-21.

4) Martin K, Wallace P, Rust P F, Garvey W T. Estimation of resting energy expenditure considering effects of race and diabetes status. Diabetes Care 2004; 27: 1405-11.

5) Ikeda K, Fujimoto S, Goto M, Yamada C, Hamasaki A, Shide K, Kawamura T, Inagaki N. Impact of endogenous and exogenous insulin on basal energy expenditure in patients with type 2 diabetes under standard treatment. Am J Clin Nutr 2011; 94: 1513-8.

6) Ryan M, Sallé A, Guilloteau G, Genaitay M, Livingstone MB, Ritz P. Resting energy expenditure is not increased in mildly hyperglycaemic obese diabetic patients. Br J Nutr 2006; 96: 945-8.

7) Harris J A, Benedict F G. A biometric study of basal metabolism in man. Washington, DC: Carnegie Institute of Washington, 1919 (Publication number 297).

8) Leung R, Woo J, Chan D, Tang N. Validation of prediction equations for basal metabolic rate in Chinese subjects. Eur J Clin Nutr 2000; 54: 551-4.

9) Case K O, Brahler C J, Heiss C. Resting energy expenditures in Asian women measured by indirect calorimetry are lower than expenditures calculated from prediction equations. J Am Diet Assoc 1997; 97: 1288-92.

10) Liu H-Y, Lu Y-F, Chen W-J. Predictive equations for basal metabolic rate in Chinese adults: A cross-validation study. J Am Diet Assoc 1995; 95: 1403-8.

11) Henry C J K, Rees D G. New predictive equations for the estimation of basal metabolic rate in tropical peoples. Eur J Clin Nutr 1991; 45: 177-85.

12) Cole T J, Henry C J K. The Oxford Brookes basal metabolic rate database- a reanalysis. Public Health Nutrition 2005; 8: 1202-12.

13) Wouters-Adeiaens M P E, Westerterp K R. Low resting energy expenditure in Asians can be attributed to body composition. Obesity 2008; 16: 2212-6.

14) Soares M J, Piers L S, O'Dea K, Shetty P S. No evidence for an ethnic influence on basal metabolism: an examination of data from India and Australia. British Journal of Nutrition 1998; 79: 333-41.

15) Miyake R, Tanaka S, Ohkawara K, Ishikawa-Takata K, Hikihara Y, Taguri E, Kayashita J, Tabata I. Validity of predictive equations for basal metabolic rate in Japanese Adults. J Nutr

Sci Vitaminol 2011; 57: 224-232.

16) Bursztein S, Elwyn D H, Askanazi J, Kinney J M. Energy metabolism, indirect calorimetry, and nutrition. Baltimore, Lippincott Williams & Wilkins, 1989.

17) Compher C, Frankenfield D, Keim N, Roth-Yousey L; Evidence Analysis Working Group. Best practice methods to apply to measurement of resting metabolic rate in adults: a systematic review. J Am Diet Assoc 2006; 106:881-903.

18) Frary CD, Johnson RK. Energy. 12th ed. In: Krause's food & nutrition therapy. Mahan LK, Escott-Stump S. 2007:22-38.

19) Japan Diabetes Society. Treatment Guide for Diabetes. Tokyo Japan, Bunkodo, 2007

20) Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. J Physiol 1949; 109: 1-9.

21) Japanese Anthropometric Reference Data. Japanese J Nutritional Assesment 2002; 19: 12-19.

22) The Committee of the Japan Diabetes Society on the diagnostic criteria of diabetes mellitus. Report of the committee on the classification and diagnostic criteria of diabetes mellitus. J Diabetes Invest 2010; 1: 212-28.

23) Weijs P J M, Vansant G A A M. Validity of predictive equations for resting energy expenditure in Belgian normal weight to morbid obese women. Clin Nutr 2010; 29: 347-51

24) Nelson KM, Weinsier RL, Long CL, Schutz Y. Prediction of resting energy expenditure from fat-free mass and fat mass. Am J Clin Nutr 1992; 56: 848-56.

25) Lean M E J, Han T S, Deurenberg P. Predicting body composition by densitometry from simple anthropometric measurements. Am J Clin Nutr 1996; 63: 4-14.

26) Johnstone A M, Rance K A, Murison S D, Duncan J S, Speakman J R. Additional anthropometric measures may improve the predictability of basal metabolic rate in adult subjects. Eur J Clin Nutr 2006; 60: 1437-44.

27) Korth O, Bosy-Westphal A, Zschoche P, Glüer C C, Heller M, Müller M J. Influence of methods used in body composition analysis on the prediction of resting energy expenditure. Eur J Clin Nutr 2007; 61: 582-9.

28) Hebert S L, Nair K S. Protein and energy metabolism in type 1 diabetes. Clinical Nutrition 2010; 29: 13-17

29) Ministry of Health, Labour and Welfare of Japan. Dietary reference intakes for Japanese, 2010 Tokyo, Japan: Daiichi Shuppan, 2009.

30) Usui C, Takahashi E, Gando Y, Sanada K, Oka J, Miyachi M, Tabata I, Higuchi M. Resting energy expenditure can be assessed by dual-energy X-ray absorptiometry in women regardless of age and fitness. Eur J Clin Nutr 2009; 63: 529-35.

383 Table 1 Characteristics of patients (derivation set).

	All	Male	Female
No. of patients	68	39	29
Type of diabetes (type1/type2) (n)	7/61	4/35	3/26
Age (years)	59.8 ± 11.2 (range 19-78)	58.3 ± 10.3	61.8 ± 12.2
Height (cm)	161.3 ± 9.5	167.6 ± 6.0	152.9 ± 6.3
Body weight (kg)	62.8 ± 14.7 (range 34.6-113.6)	67.3 ± 16.0	56.7 ± 10.2
BMI (kg/m^2)	24.0 ± 4.7	23.9 ± 5.3	24.2 ± 3.8
FFM (kg)	47.7 ± 10.6	53.4 ± 9.4	39.9 ± 6.5
Fat mass (kg)	16.0 ± 7.0	14.8 ± 8.0	17.8 ± 4.9
TSF (mm)	15.9 ± 7.8	13.1 ± 6.5	19.8 ± 7.8
AMA (cm^2)	44.6 ± 10.2	48.9 ± 9.7	38.8 ± 7.9
Waist (cm)	86.5 ± 12.4	86.2 ± 14.0	86.9 ± 10.3
Hip (cm)	91.3 ± 7.8	92.4 ± 8.5	89.8 ± 6.7
BEE (kcal/day)	1290 ± 217	1395 ± 210	1149 ± 130
FPG (mg/dL)	113.7 ± 25.8	113.3 ± 25.5	114.3 ± 26.6
PPPG (mg/dL)	143.5 ± 35.9	146.5 ± 39.7	139.3 ± 30.3
HbA1c (%)	10.5 ± 2.5	10.3 ± 2.4	10.8 ± 2.7
Duration of diabetes (years)	9.3 ± 7.8	10.9 ± 8.9	7.1± 5.5
Treatment			
Diet (kcal/SBW/day)	29.1 ± 2.5	28.9 ± 2.1	29.3 ± 3.0
Medications			
Ins only (n)	34	21	13

Ins + Met (n)	10	4	6
Ins + SU (n)	3	2	1
Ins + SU + Met (n)	1	0	1
SU (n)	8	5	3
SU + Met (n)	5	2	3
Met only (n)	4	3	1
None (n)	3	2	1

[1]Data are means ± SD. BMI, body mass index; FFM, fat-free mass; TSF, triceps-skinfold thickness; AMA, arm muscle area; Waist, waist circumference; Hip, hip circumference; BEE, basal energy expenditure; FPG, fasting plasma glucose just before the measurement of BEE; PPPG, mean preprandial plasma glucose for three consecutive days before the measurement of BEE; HbA1c, glycated hemoglobin; SBW, standard body weight; Ins, insulin; SU, sulfonylurea; Met, metformin.

Table 2 Correlations between FFM, fat mass and anthropometric indices.

	FFM	FM	Ht	Wt	TSF	AMA	Waist	Hip
FFM	1.00	—	—	—	—	—	—	—
FM	0.38†	1.00		—	—	—	—	—
Ht	0.75‡	-0.12	1.00	—	—	—	—	—
Wt	0.90‡	0.75‡	0.49‡	1.00	—	—	—	—
TSF	0.13	0.78‡	-0.30*	0.46‡	1.00	—	—	—
AMA	0.84‡	0.48†	0.50‡	0.83‡	0.07	1.00	—	—
Waist	0.56‡	0.91‡	0.02	0.83‡	0.70‡	0.60‡	1.00	—
Hip	0.73‡	0.79‡	0.28*	0.90‡	0.50‡	0.73‡	0.83‡	1.00

Pearson's correlation coefficients (*n*=68):*p<0.05; †p<0.01; ‡p<0.001. FFM, fat-free mass; Ht, height; Wt, weight; TSF, triceps-skinfold thickness; AMA, arm muscle area; Waist, waist circumference; Hip, hip circumference.

Table 3 Results of multiple regressions for FFM, FM and BEE.

	Adj. R^2		Model
FFM = − 26.9 + 0.5×Wt + 0.3×Ht − 0.1×Age + 3.9×Sex [a]	0.95		1
FFM = − 60.8 + 0.6×AMA + 0.5×Ht [b]	0.84		2
FFM = − 102.8 + 0.8×Hip + 0.5×Ht + 4.5×Sex [c]	0.87		3
FM = −26.3 + 0.5×Waist − 2.6×Sex [c]	0.86		4
FM = − 45.4 + 0.5×Hip + 0.4×TSF + 0.1×Age [d]	0.84		5
FM = − 14.3 + 0.4×Wt + 0.2×TSF + 0.1×Age − 5.1×Sex	0.87		6
BEE = 691.6 + 11.6×FFM + 8.9×FM − 2.6×Age + 106.7×Sex	0.81		7
BEE = 748.4 + 10.4×Wt − 3.0×Age + 125.4×Sex [e]	0.81	Model (1 + 6)	8
BEE = − 332.3 + 6.1×Ht + 9.5×Waist − 4.6×Age +147.1×Sex [f]	0.73	Model (2 + 4)	9
BEE = − 1139.3 + 13.8×Hip + 6.1×Ht +5.6×TSF +157.9×Sex [c]	0.77	Model (3 + 5)	10

FFM, fat-free mass (kg); FM, fat mass (kg); BEE, basal energy expenditure (kcal/day); Wt, body weight (kg); Ht, height (cm); AMA, arm muscle area (cm^2); Hip, hip circumference (cm); Waist, waist circumference (cm); TSF, triceps-skinfold thickness (mm); Adj. R^2, adjusted coefficient of determination.

[a] Male = 1, female = 0.

[b] Age and sex were not significant determinants when added to this model.

[c] Age was not a significant determinant when added to this model.

[d] Sex was not a significant determinant when added to this model.

[e] Height and TSF were not significant determinants when added to this model.

[f] AMA was not a significant determinant when added to this model.

Table 4 Detailed result of model 8.

Dependent variable BEE [a]	Coef. [b]	95% CI [c]		Std. coef. [d]	P>t	Adj. R^{2} [e]
Independent variables						
Intercept	748.4	562.6	934.1		<0.001	0.810
Wt (kg)	10.4	8.6	12.1	0.70	<0.001	
Age (year)	-3.0	-5.2	-0.9	-0.16	0.007	
Sex (male=1, female=0)	125.4	75.6	175.1	0.29	<0.001	

[a] BEE, basal energy expenditure (kcal/day).

[b] Coef., partial regression coefficient.

[c] CI, confidence interval.

[d] Std. coef., standardized coefficient.

[e] Adj. R^2, adjusted coefficient of determination.

Table 5 Equations to estimate BEE [a].

	Formula	Reference
New equation	10 W – 3 A + 125 (if male) + 750 [b, c]	
Harris and Benedict (1919)	Male: 13.75 W +5.00 H -6.76 A + 66.47 [d]	7
	Female: 9.56 W + 1.85 H – 4.68 A + 655.10	
Oxford (2005)	Male: 18-30 years; 16.0 W + 545	12
	30-60 years; 14.2 W + 593	
	60 + years; 13.5 W + 514	
	Female: 18-30 years; 13.1 W + 558	
	30-60 years; 9.74 W + 694	
	60 + years; 10.1 W + 569	
Liu (1995)	13.88 W + 4.16 H – 3.43 A – 112.40 (if female) + 54.34	10
Ganpule (2007)	(48.1W + 23.4H – 13.8A – 547.3(if female) – 423.5)/4.186	15

[a]BEE, basal energy expenditure (kcal/day).

[b]W, weight (kg).

[c] A, age (year).

[d] H, height (cm).

Table 6 Characteristics of patients (validation set).

	all	Male	Female
No. of patients	60	36	24
Type of diabetes (typ1/type2) (n)	6/54	3/33	3/21
Age (years)[2]	58.9 ± 13.3 (range 21-82)	55.8 ± 13.5	63.6 ± 11.8
Body weight (kg)[2]	66.9 ± 18.2 (range 41.1-138.0)	70.0 ± 19.2	62.2 ± 15.8
BMI (kg/m^2)	25.7 ± 6.7	24.6 ± 6.2	27.5 ± 7.2
BEE (kcal/day)[2]	1260 ± 219	1342 ± 225	1137 ± 141
FPG (mg/dL)	132.1 ± 20.8	130.8 ± 20.5	133.9 ± 21.6
PPPG (mg/dL)	157.6 ± 32.3	156.7 ± 34.8	159.0 ± 28.9
HbA1c (%)	9.3 ± 1.5	9.5 ± 1.8	9.0 ± 1.1
Duration of diabetes (years)	10.0 ± 8.8	9.3 ± 8.4	11.0± 9.5
Treatment			
Diet (kcal/SBW/day)	29.4 ± 2.8	29.4 ± 3.0	29.4 ± 2.5
Medications			
Ins only (n)	28	15	13
Ins + Met (n)	2	1	1
Ins + SU (n)	2	2	0
SU (n)	13	9	4
SU + Met (n)	4	4	0
Met only (n)	3	1	2
None (n)	8	4	4

Data are means±SD. BMI, body mass index; BEE, basal energy expenditure; FPG, fasting plasma glucose just before the measurement of BEE; PPPG, mean preprandial plasma glucose for three consecutive days before the measurement of BEE; HbA1c, glycated hemoglobin; SBW, standard body weight; Ins, insulin; SU, sulfonylurea; Met, metformin.

Table 7 Evaluation of equations in validation set.

Equation	Estimated BEE per body [a]	Estimated BEE per kg Wt [b]	Bias [c]	RMSE [d]	Accurate estimation [e]
New equation	1317 ± 227	20.2 ± 2.3	4.8 ± 7.7	103	78
Harris and Benedict	1388 ± 309	21.1 ± 2.2	9.8 ± 9.4	184	50
Oxford	1420 ± 309	21.6 ± 2.3	12.3 ± 9.5	209	38
Liu	1407 ± 321	21.3 ± 2.1	11.1 ± 10.9	205	42
Ganpule	1323 ± 295	20.1 ± 2.4	4.5 ± 10.5	140	63

n = 60. Data are means ± SD.

[a] Estimated BEE per body, mean basal energy expenditure estimated per body (kcal/day)

[b] Estimated BEE per kg Wt, mean basal energy expenditure estimated per kg body weight (kcal/kg/day)

[c] Bias, mean percentage error between estimated and measured BEE ((BEE estimated – BEE measured) / BEE measured) (%)

[d] RMSE, root mean squared error (kcal/day)

[e] Accurate estimation, percent of the patients estimated by each equation within 10% of measured value (%).