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

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

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29
30 A part of this study was presented in abstract form at the annual meeting of American
31 Diabetes Association, New Orleans, Louisiana, 5-9 June 2009.

32 ABSTRACT(<200 words)

33 Background & Aims

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

38

39 Methods

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

45

46 Results

47 The best-fit equation was $BEE[kcal/day] = 10 \times (body\ weight)[kg] - 3 \times (age)[y] + 125(\text{if male})$
48 $+ 750$. Adjusted coefficient of determination was 81.0%. Root mean squared errors and
49 accurate prediction in the validation set were 103 kcal/day and 78% for the new equation; 184
50 and 50 for Harris-Benedict; 209 and 38 for Oxford; 205 and 42 for Liu; and 140 and 63 for

51 Ganpule.

52

53 Conclusions

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

56

57 Keywords: basal metabolic rate; resting metabolic rate; indirect calorimetry; prediction
58 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

77 non-Caucasians (12). However, REE is similar in Asians and Caucasians after adjustment for
78 FFM, and BEE in Indians and Australians is similar after adjustment for FFM and fat mass
79 (13, 14). To date, there are few equations to estimate energy expenditure specifically in Asian
80 populations (10, 15).

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

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

89

90 2. Patients, materials and methods

91 Patients

92 Japanese patients with type 1 or type 2 diabetes admitted to the Department of

93 Diabetes and Clinical Nutrition, Kyoto University Hospital, Kyoto, Japan for diabetes

94 self-management education during the period of December 2007 through September 2009

95 were recruited for derivation study. Written, informed consent was obtained from all

96 participants. During hospital stay, the participants had a prescribed diet with or without

97 medications including oral hypoglycemic agents and insulin according to the treatment guide

98 for diabetes of the Japan Diabetes Society (19). Their physical activity was not restricted, but

99 they did not engage in vigorous exercise. Participants were screened by medical history,

100 physical examination, and laboratory testing to assure the absence of hepatic, pulmonary,

101 thyroid, cardiac and renal dysfunction, macroalbuminuria, inflammatory diseases, and

102 malignant tumors. Those who took steroids or beta blockers or had physical disabilities were

103 excluded. The study protocol was approved by Kyoto University Graduate School and Faculty

104 of Medicine, Ethics Committee.

105

106 Indirect calorimetry

107 Basal energy expenditure (BEE) was measured in the morning under glycemic

108 control with prescribed diet (29.1 ± 2.5 kcal/kg of standard body weight per day consisting of
109 52% carbohydrate, 20% protein, and 28% fat in energy component) and with medications
110 when needed. Standard body weight (kg) was calculated by multiplying 22 (kg/m^2) by square
111 of height (m). Whole-body oxygen consumption (VO_2) and carbon dioxide production
112 (VCO_2) was measured for more than 10 minutes with indirect calorimetry (AE300S, Minato
113 Medical Science, Osaka, Japan) by one investigator (KI) at the bedside of each patient under
114 the strict condition described previously (5, 16, 17). Briefly, an afebrile patient in a
115 post-absorptive state after an overnight fast (14 hours) with <180 mg/dL capillary plasma
116 glucose remained in a supine position after waking on the bed in the ward without smoking or
117 taking caffeine, and the measurements were performed at room temperature between 22°C
118 and 27°C . After discarding the initial 5 minutes of recording, we took 5-minutes of data, in
119 accord with the steady state definition (17), during which the coefficient of variation for VO_2
120 per minute and VCO_2 per minute was achieved $\leq 10\%$, and applied them to the Weir formula
121 with 24-hour urinary urea nitrogen (20).

122

123 Anthropometry and body composition

124 Height was measured on the day of admission. Body weight, skinfold thickness, and
125 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; $AMC [cm] = MAC [cm] - \pi \times TSF [mm] / 10$, $AMA [cm^2] = (AMC [cm])^2 / 4\pi$. 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.

137

Other measurements

Glycated hemoglobin was measured by use of HPLC (ADAMSTM 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

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

149

150 Testing the new equation

151 A separate data set of Japanese patients with type 1 or type 2 diabetes admitted to the
152 same department for the same purpose during the period of June 2005 through December
153 2007 was drawn from the medical records for validation study. Inclusion/exclusion criteria
154 and dietary condition during hospital stay were similar to that of the derivation sample.

155 Whole-body VO_2 and VCO_2 was measured after an overnight fast (14-16 hours) for
156 more than 15 minutes with the same calorimetry by one investigator (MI) on the same
157 condition. Each patient was conveyed from their ward to the examination room by a
158 healthcare staff member in a wheel chair and they rested in bed in a supine position for 30
159 minutes before the measurement of BEE. BEE was calculated from VO_2 and VCO_2 by use of
160 Elwyn formula ($\text{BEE [kcal/day]} = 3.581 \times \text{VO}_2 [\text{L/day}] + 1.448 \times \text{VCO}_2 [\text{L/day}] - 32.4$) (16).
161 Body weight was measured on the day of calorimetry.

162 The protocol of this validation study was also approved by Kyoto University

163 Graduate School and Faculty of Medicine, Ethics Committee.

164

165 Statistical analysis

166 Numerical data are summarized as means $\pm$ SDs. Categorical data were treated as

167 dummy variables.

168 We first explored good estimators for FFM and fat mass in anthropometric indices,

169 such as body weight, height, TSF, AMA, waist circumference and hip circumference, because

170 FFM and fat mass are known as two major estimators of BEE. Correlations between these

171 variables were evaluated by Pearson's correlation analysis. Multiple linear regression analysis

172 was then performed to evaluate the contribution of anthropometric indices, age, and sex to

173 FFM and fat mass. Next, a best-fit equation to estimate BEE from anthropometric indices, age,

174 and sex was explored by multiple linear regression analysis with consideration of estimators

175 of FFM and fat mass.

176 For testing the validity of our new equation and comparing it with existing prediction

177 equations, we calculated measures of accuracy. The mean percentage difference between BEE

178 estimated and measured (bias) was considered systematic error. The root mean squared error

179 (RMSE) was considered to reflect each individual's error range unrelated to whether it was

180 over or under estimation. The proportion of patients with BEE estimated within $\pm 10\%$ of BEE

181 measured was considered another measure of accuracy (23).

182 Data were analyzed by use of Stata 11.0 (Stata Corporation, College Station, TX,

183 USA). Statistical significance was set at $P < 0.05$ (2-tailed).

184

185 3. Results

186 Data were obtained and analyzed in 68 patients, of which 7 had type 1 diabetes and
187 61 had type 2 diabetes. Mean glycated hemoglobin (HbA1c) on admission was as high as
188 10.5%, but mean fasting plasma glucose just before the measurement of BEE (FPG) was as
189 low as 113.7 mg/dL due to the treatments during hospital stay (**Table 1**). Additional
190 characteristics of patients in the derivation set and the results of measurement are shown in

191 **Table 1.**

192 Body weight had the highest correlation with FFM ($r = 0.90$), followed by arm
193 muscle area (AMA), height and hip circumference ($r = 0.84, 0.75$ and 0.73 , respectively)
194 (**Table 2**). Waist circumference had the highest correlation with fat mass ($r = 0.91$), followed
195 by hip circumference, triceps-skinfold thickness (TSF) and body weight ($r = 0.79, 0.78$ and
196 0.75 , respectively).

197 In regression analysis for FFM, we selected body weight, AMA, height and hip
198 circumference as potent estimators together with other plausible estimators, age and sex. As
199 both AMA and hip circumference were strongly correlated with body weight and AMA was
200 also strongly correlated with hip circumference, to analyze these three variables separately,
201 we used three sets of independent variables, (body weight, height, age and sex), (AMA,
202 height, age and sex), and (hip circumference, height, age and sex). The regressions revealed

203 that all four variables were significant estimators for FFM in the first analysis (model 1 in
204 **Table 3**), that AMA and height were significant in the second analysis (model 2) and that hip
205 circumference, height and sex were significant in the third analysis (model 3). The first four
206 variables accounted for 95% of variation in FFM, the second two variables 84%, and the third
207 three variables 87%. For fat mass, we selected another three sets of independent variables,
208 (waist circumference, age and sex), (hip circumference ,TSF, age and sex) and (body weight,
209 TSF, age and sex) because waist circumference had a strong correlation with hip
210 circumference, TSF and body weight, and hip circumference also had a strong correlation
211 with body weight. In the first analysis, only waist circumference and sex were significant
212 estimators for fat mass, accounting for 86% of fat mass (model 4). In the second analysis, hip
213 circumference, TSF and age were significant, accounting for 84% of fat mass (model 5). In
214 the third analysis, body weight, TSF, age and sex were significant, accounting for 87% of fat
215 mass (model 6).

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

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

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

230 **$BEE = 10 \times \text{body weight} - 3 \times \text{age} + 125 \text{ (if male)} + 750$.**

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

232 The bias of this equation in the derivation set was $-1.2 \pm 6.4\%$; RMSE was 94
233 kcal/day; accurate estimation was 91%.

234 We then tested this new equation in a separate validation data set comparing it with
235 existing equations (**Table 5**). Characteristics of patients in the validation set are shown in
236 **Table 6**. The ratio of patients with type 1 and 2 diabetes was almost the same as in the
237 derivation set. Mean age was similar to that in the derivation set, but there were more obese
238 people in the validation set. FPG and PPPG, which represent the glycemic levels around the

239 time of measurement of BEE, were higher, but HbA1c on admission was lower than that in
240 the derivation set. Mean duration of diabetes was similar to that in the derivation set.
241 Prescribed diet was almost the same as in the derivation set, but treatment with insulin was
242 more common in the derivation set. The bias of the new equation was $4.8 \pm 7.7\%$, RMSE was
243 103 kcal/day, and the percent of patients estimated within 10% of measured value was 78 %.
244 The new equation had better validity than Harris and Benedict equation, Oxford equation, or
245 the Liu equation and Ganpule equation (**Table 7**).

246

247 4. Discussion

248 We report a new equation to estimate BEE in Japanese patients with diabetes with
249 higher accuracy compared to existing equations. As in other BEE estimation equations, the
250 main estimator was FFM and additional estimators were fat mass, age and sex (2-4, 24).

251 Stepwise estimation analysis of the estimators of FFM and fat mass in the present study
252 revealed that no other indices improved fitting of the equation for BEE except body weight,
253 age and sex. Although anthropometric indices are good estimators for body composition and
254 they improve predictability of certain equations for BEE (25, 26), they were not as effective
255 as body weight in the present study. This accords with the finding that the standard error of
256 the estimate of REE prediction by weight, height, sex and age was well within the range of
257 the standard error of estimates from other FFM-derived prediction equations (27). Since
258 ethnic difference in BEE is derived from differences in body composition (13), an
259 ethnicity-specific constant term could more precisely estimates BEE (4, 12), but an
260 ethnicity-specific coefficient of anthropometry is also valid.

261 We compared our new equation with existing equations such as Harris and Benedict,
262 Oxford, Liu, and Ganpule because the Harris and Benedict equation is widely known in
263 clinical practice in Japan, the Oxford equation was recently developed from a large number of
264 subjects including many ethnicities, and the Liu equation and Ganpule equations were derived

265 from Chinese and Japanese subjects, respectively (7, 10, 12, 15). The validation analysis
266 revealed better validity of the new equation in Japanese patients with diabetes than any of the
267 other equations.

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

275 There are potential weaknesses of the present study. First, only a small number of
276 patients with type 1 diabetes was included. However, no difference in the value of BEE
277 between patients with type 1 and type 2 diabetes has been described to date. In type 1 diabetes,
278 the elevated energy expenditure is observed only during insulin deprivation, and it returns to
279 normal level by insulin treatment (28). In type 2 diabetes, there is no difference in
280 FFM-adjusted REE between mildly hyperglycemic patients and controls (6). Thus, when they
281 are under treatment, BEE in both type 1 and type 2 diabetes patients can be assumed
282 comparable to that in healthy people. In addition, our validation data set has more background

283 in common with the derivation set than the general population of Japanese patients with
284 diabetes. We also did not measure BEE of healthy Japanese for comparison. It remains to be
285 established whether or not the difference in BEE between Japanese patients with diabetes and
286 healthy Japanese is insignificant when FPG of patients are <180 mg/dL.

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

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

296

297 Statement of Authorship

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

302 Conflict of Interest & Acknowledgements

303 None of the authors had any conflict of interest.

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310

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382

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

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

390 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.

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

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

393 FFM, fat-free mass (kg); FM, fat mass (kg); BEE, basal energy expenditure (kcal/day); Wt,
 394 body weight (kg); Ht, height (cm); AMA, arm muscle area (cm²); Hip, hip circumference
 395 (cm); Waist, waist circumference (cm); TSF, triceps-skinfold thickness (mm); Adj. R^2 ,
 396 adjusted coefficient of determination.

397 ^a Male = 1, female = 0.

398 ^b Age and sex were not significant determinants when added to this model.

399 ^c Age was not a significant determinant when added to this model.

400 ^d Sex was not a significant determinant when added to this model.

401 ^e Height and TSF were not significant determinants when added to this model.

402 ^f AMA was not a significant determinant when added to this model.

403

404 Table 4 Detailed result of model 8.

Dependent variable			Std.		Adj.	
BEE ^a	Coef. ^b	95% CI ^c		coef. ^d	P>t	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	

405 ^a BEE, basal energy expenditure (kcal/day).

406 ^b Coef., partial regression coefficient.

407 ^c CI, confidence interval.

408 ^d Std. coef., standardized coefficient.

409 ^e Adj. R², adjusted coefficient of determination.

410

411 Table 5 Equations to estimate BEE ^a.

	Formula	Reference
New equation	$10 W - 3 A + 125 \text{ (if male)} + 750^{b, c}$	
Harris and Benedict (1919)	Male: $13.75 W + 5.00 H - 6.76 A + 66.47^d$ Female: $9.56 W + 1.85 H - 4.68 A + 655.10$	7
Oxford (2005)	Male: 18-30 years; $16.0 W + 545$ 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; $10.1 W + 569$	12
Liu (1995)	$13.88 W + 4.16 H - 3.43 A - 112.40 \text{ (if female)} + 54.34$	10
Ganpule (2007)	$(48.1W + 23.4H - 13.8A - 547.3 \text{ (if female)} - 423.5)/4.186$	15

412 ^aBEE, basal energy expenditure (kcal/day).

413 ^bW, weight (kg).

414 ^cA, age (year).

415 ^dH, height (cm).

416

417 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

418 Data are means $\pm$ SD. BMI, body mass index; BEE, basal energy expenditure; FPG, fasting
419 plasma glucose just before the measurement of BEE; PPPG, mean preprandial plasma glucose
420 for three consecutive days before the measurement of BEE; HbA1c, glycated hemoglobin;
421 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 (%).