Development of a predictive equation for estimating Resting Energy Expenditure in overweight people over 55 years of age

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Acknowledgement

In this thesis the evaluation of current equations and the development of a predictive equation about the estimation of resting energy expenditure in overweight people over 55 years of age is described. We wrote this thesis to complete the study of ‘Nutrition and Dietetics’ at the University of Applied Sciences Amsterdam. It was accomplished from the 4th of February until the 3rd of June 2013.

The data collected for this thesis were from different weight loss trials of the Nutrition Laboratory at the University of Applied Sciences Amsterdam. In the Nutrition Laboratory special measurement equipment was used to collect them.

Our special thanks go out to Ir. A.M. Verreijen for her professional advice, clear explanations and feedback on our thesis. We would also like to thank Dr. Ir. Weijs for his view on our thesis and his expertise.

We are also very grateful for the guidance and alacrity of our practical supervisor Nutrition Laboratory S.E. van der Plas.

Without the research teams and participants of the different weight loss trials it would not have been possible to collect all the data, and therefore we would like to thank them all for their aid and participation.

Amsterdam, June 17th 2013

Anna Rootjes and Roos Klaver
Abstract

**Background:**
Predictive equations are often used to estimate resting energy expenditure (REE). Since body composition changes towards less fat-free mass (FFM) and more fat mass (FM) during aging, equations based on a younger reference population might not be accurate for overweight people over 55 years of age.

**Aim:**
To make a hypo caloric diet, the development of an accurate predictive equation in overweight people over 55 years of age was desirable. The objective was to evaluate the accuracy of current equations and develop a new predictive equation for this specific population.

**Methods:**
In this study, baseline measurements were performed in 81 subjects over 55 years of age with a body mass index (BMI) of ≥28 kg/m² from different weight-loss studies. REE, weight, height, age, gender, FFM and FM were measured. REE was measured with a ventilated hood system (Vmax Encore n29), FFM and FM were measured using air displacement plethysmography (BODPOD Life Measurement Inc, Concord, CA). Measured REE was used as reference and compared with 69 predictive equations for estimating REE, of which 56 equations based on weight and height and 13 equations based on FFM and FM. By using linear regression techniques, new equations were developed. The accuracy of the REE equations was evaluated on the basis of the percentage within 10% of REE measured. Statistical techniques were used to evaluate the current equations in comparison with the newly developed equations: root mean squared error (RMSE), concordance correlation coefficient (CCC), Bland-Altman plots.

**Results:**
Accuracy of current equations and the newly developed equations were tested. When comparing predictive equations based on weight and height, Korth et al. (72.8% accurate prediction; RMSE 193; CCC 0.776) and the newly developed Klaver-Rootjes Gender equation (69% accurate prediction; RMSE 183; CCC 0.776) gave the most accurate values. The equation based on FFM and FM with the highest values of accurate prediction was the newly developed Klaver-Rootjes equation (70.4% accurate prediction; RMSE 178; CCC 0.792).

**Conclusion:**
The equations from Korth et al., Klaver-Rootjes, and Klaver-Rootjes Gender predicted REE most accurately in this study. To evaluate whether the Klaver-Rootjes equation is accurate in another overweight population, cross-validation is necessary.

**Key words:** Resting energy expenditure, overweight, predictive equation, weight, fat-free mass
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Introduction

On a global scale, overweight and obesity have continued to be health issues that are increasing in size and severity. In a report made by World Health Organization (WHO) in 2009, it is estimated that a total of 1.5 billion people will be overweight in 2015. In comparison, 1 billion people were overweight with a body mass index (BMI) of ≥25 kg/m² in 2005. More than 300 million of them were obese (BMI≥30 kg/m²). When looking at a list of the top 10 risk factors included in the report for high-income countries, overweight and obesity are ranked third regarding causes of death. Obesity and overweight are caused by an energy imbalance between calories consumed and calories expended. Thus, it appears that the last few years there has been an increased intake of energy-dense foods that are high in fat, salt and sugars, but low in vitamins, minerals and other micronutrients. Simultaneously, over the years on a global scale physical activity has decreased.

The prevalence of overweight and obesity in The Netherlands is comparable to a global prevalence. In 1981, 27.4% of the Dutch population was overweight. Of this percentage, 22.9% had a BMI of ≥25 kg/m² and 4.4% had a BMI of ≥30 kg/m². In 2011 the Dutch population with a BMI of ≥25 kg/m² had increased to 41.7% and the population with a BMI of ≥30 kg/m² was 9.8%. The prevalence of overweight and obesity in the group over 55 years of age have the highest percentage (56.2-59.0%). It can be concluded that in twenty years’ time overweight and obesity have increased significantly. Besides, in the Netherlands this has been and still is a growing problem.

The last few decades the number of people getting older has been on the increase. From 2011- 2016, the number of elderly people in the Netherlands, that is people above the age of 65, will increase to 2.5-3 million. This is a significant increase in comparison with the years 2006-2011: 2.3-2.5 million. In the year 2011, the so-called baby boom generation, people of 65 years and older, reached a general retirement age. This generation consists of people born just after the Second World War. This generation accounts for a major part of the elderly. Therefore the number of overweight elderly will increase. In 2040 there will be 4.5 million obese elderly in the Netherlands.

It is known that overweight and obesity are linked to comorbidities such as cardiovascular disease, hypertension, diabetes and some cancers. Besides, obesity causes several social, psychical and psychological problems and, this way, it reduces the quality of life. All these comorbidities are reasons to reduce overweight and obesity.
Most of the studies show a positive relationship between mortality risk and a BMI of ≥30 kg/m² for elderly people. However, in the review by Janssen and Mark a positive relationship is found between mortality risk and a BMI of ≥27 kg/m² in older adults. The relationship between mortality risk and BMI is shown as a U-shaped curve with a large flat bottom. From a BMI of 27 kg/m² and higher until a BMI of 31-32 kg/m² there is a small increase of the mortality risk in older adults. After a BMI of 31-32 kg/m² there will be a stronger increase. There are insufficient data available to define cut-off points for older adults to determine obesity.

Currently there is a guideline for treatment of overweight and obesity from the CBO which is intended for children and adults. This guideline advises an energy intake of 600 kilocalories less than the daily energy expenditure. For exercise this guideline advises one hour a day with moderate intensity and to engage in an 30-60 minutes aerobic exercise on 60-80% of the maximum heart rate three times a week. Cognitive behavioural therapy can be considered to achieve behavioural changes.

These guidelines are not specifically developed for people over 55 years of age. Furthermore, schedules for losing weight for young adults can probably not be transferred to older people. Because there are no specific guidelines in the Netherlands for older people, it is not clear how dieticians should treat older people and which obstacles dieticians come across. Aging is associated with considerable changes in body composition. Therefore, the current guidelines could and probably should be more specified for overweight people over 55 years of age.

During aging people’s body composition changes. Maximal fat-free mass (FFM) is usually developed at the age of approximately 20 years. FFM consists of primarily skeletal muscle, body water, organs and bones. After the age of 30 years up to 40% of FFM progressively decreases, while fat mass (FM) increases. These changes in body composition will continue up to the age of 60-70. When the elderly reach the age of 70 years both FFM and FM decrease. The maximal FM is usually reached at the age of approximately 60-70. The loss of FFM will continue for people over 70 years of age. This loss of FFM is mainly muscle mass loss. This process of losing muscle mass and/or loss in muscle strength and function during aging is named sarcopenia. This condition might lead to disability, hospitalization and, ultimately, death.

Since the guidelines for the treatment of obesity advise an intake of 600 kcal less than the estimated amount, it is necessary to measure the resting energy expenditure (REE) accurately. The measurement of REE with indirect calorimetry (IC) is often regarded as a reference method.
It measures oxygen consumption and carbon dioxide production. If it is not possible to measure REE directly, a predictive equation is necessary. The estimated REE can be multiplied by Physical Activity Level to calculate Total Energy Expenditure.

Nowadays fewer than approximately 50% of the dieticians in the Netherlands do not estimate energy expenditure at all. The dieticians who do estimate energy expenditure use an equation.

The most commonly used equation in the Netherlands is the Harris and Benedict 1984. It is developed to estimate REE in adolescents and adults. In a review from Frankenfield et al. 25 studies evaluated the Harris and Benedict 1984 equation. From this review it can be concluded that an accurate prediction of REE occurred only in 45-80% of the subjects. Most of these studies overestimate REE in adolescents and adults.

Studies from literature suggest a decrease in total energy expenditure (TEE) during aging which is not caused by a lower energy intake. After 20 years of age REE decreases 2-3% every decade. 75% of this decrease is due to the loss of FFM. The reduction of the physical activity during aging causes also the loss of TEE. Aging causes hormonal changes and this is also associated with the reduction of FFM. If, for example, a reduced FFM causes a lower REE in people over 55 years of age, it might be a predictor in an equation for estimating REE.

The current predictive equations are usually developed on a younger reference population. Therefore, equations might overestimate REE in people over 55 years of age due to considerable changes in body composition while aging. The body composition consists of relatively more FM per kg body weight in comparison with younger adults. Furthermore, the population of overweight people over 55 years of age is increasing. For dietary assessment the development of an accurately predictive equation is necessary in overweight people over 55 years of age. During this graduation program a new predictive equation will be developed. Therefore, the aim of this thesis is to:

Evaluate current equations and develop a new predictive equation for estimating Resting Energy Expenditure in overweight people over 55 years of age.
**Methods**

Since 2006 several weight loss trials have been conducted in the Nutrition laboratory of the Department of Nutrition and Dietetics, Hogeschool van Amsterdam, University of Applied Sciences, The Netherlands. Under standardized conditions REE, weight and height, FFM and FM were measured at baseline in overweight subjects. The measured REE with IC was used as reference. Overweight people over 55 years of age with a BMI of ≥28 kg/m² were selected. Based on these data, already published equations for estimating REE were evaluated. Furthermore, four more equations were developed by using linear regression techniques: one equation based on weight and height with gender included as variable, one equation based on FFM and FM with gender included as variable and two equations based on weight and height for males and females separately. These newly developed equations were also evaluated on accuracy. In this method section first the inclusion of the subjects is described. Secondly, measurements will be explained. Finally, the applied statistics are elucidated.

**Subjects**

Subjects for these weight loss trials were recruited for participation by the distribution of flyers and posters in Amsterdam Nieuw West. An advertisement was placed in the local newspaper Westerpost. The subjects included in the data analysis were ≥55 years of age with a BMI of ≥28 kg/m². The subjects were included when data were available about antropometrics and body composition: weight, height, FFM and FM. If subjects had eaten 3-5 hours, had drunk 1 hour or had been physically active within 14 hour before the measurement, the subjects were excluded. If the respiratory quotient (RQ) was higher than 1, the data from IC was regarded as invalid and the subject was excluded. All subjects gave informed consent during screening before the baseline measurement. All procedures were in accordance with the ethical standards of the institution.

**Measurements**

The following data were collected for the evaluation of current equations and development of a new predictive equation in overweight people over 55 years of age: gender; age in years; height in cm measured by a stadiometer (Seca 222; Seca, Hamburg, Germany); body weight, FFM and FM in kg assessed by using the BodPod system (Life Measurement Inc, Condord, CA); and REE in kcal/d measured by IC with a ventilated hood system (Vmax Encore n29; Viasys Healthcare, Houten, The Netherlands). Each measurement was performed with equipment belonging to Nutrition laboratory and according to the manual.


**Indirect calorimetry**

The REE of the subjects was measured by using IC. This ventilated hood system of the IC was calibrated for volume with two standard gasses every day before the first measurement. While measuring, the ventilated hood system was recalibrated every five minutes. The subjects were in a supine and awake position. The IC measured oxygen consumption and carbon dioxide production which was calculated for a 24h period (kcal/d) by using the Weir formula. Each measurement took approximately 25 minutes and only the steady state period was selected according to the procedures of the IC. The steady state period was reached if the oxygen consumption and the carbon dioxide production changed with <10%.

**BodPod**

By using the BodPod system body weight, FFM and FM of the subjects was measured. The BodPod system was calibrated every morning and before each measurement. The body volume of the subjects was measured with an air-displacement cabin. The subjects had to wear tightly fitting underwear or bathing clothes and a swimming cap. They were not allowed to wear jewelry. During two measurements of one minute each, the body volume of the subject was measured. If the difference in body volume between the two measurements was less than 0.2 L, the measurement was completed. The density could be calculated from measured body weight and body volume. The Siri formula calculated body fat percentage, FFM and FM in kg.

**Selection of predictive equations from literature**

In 2008 Weijs published an article in which equations are evaluated for predicting REE in US and Dutch overweight adults 18-65 years. The same equations included the article from Weijs 2008, were included in this thesis. Additionally, equations are searched through PubMed. Mesh-derived terms used were: basal metabolism, energy metabolism, IC and additional terms (predict*, estimate*, equation*, and formula*) in every possible combination. Limitations placed on initial search strategies were: human subjects, age ≥18, English language. Articles from journals with an Impact Factor (IF) >1.5 were included. Main exclusion criteria were as follows: age ≤18, critically ill patients, specific ethnic groups and small sample size (n<50). After literature research, four more recent equations were included (Lazzer et al. 2010, Lazzer et al. 2010 FFM, Lührmann et al. 2002 and an unpublished equation of Weijs et al. 2010).

For each subject all predictive equations for REE in kcal/d were compared with measured REE by IC. For this calculation actual body weight or FFM at the time of the IC measurement was used.
69 predictive equations were included in this study. Table 1A presents the equations using age, weight, height, BMI and gender. Table 1B presents the current equations including age, FFM, FM, BMI and gender.
Table 1A: Predictive equations for resting energy expenditure using age, weight, height, BMI and gender.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Reference population</th>
<th>Predictive equations for estimating REE in kcal/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bernstein et al.</td>
<td>N= 202</td>
<td>M: 48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F: 154</td>
</tr>
<tr>
<td>FAO/WHO/ UNU 1985</td>
<td>N= 11.000</td>
<td>M: 30-60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F: 30-60</td>
</tr>
<tr>
<td>HB 1919</td>
<td>N= 239</td>
<td>M: 136</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F: 103</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F: 169</td>
</tr>
<tr>
<td>Henry</td>
<td>N= 2901</td>
<td>M: 534</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F: 103</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Age in y</th>
<th>HT (cm)</th>
<th>WT (kg)</th>
<th>BMI (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>48</td>
<td>40.4 ± 12.6</td>
<td>177 ± 5.8</td>
<td>60.0-204</td>
<td>103 ± 26.0</td>
</tr>
<tr>
<td>F</td>
<td>154</td>
<td>39.4 ± 12.0</td>
<td>164 ± 6.3</td>
<td>11.02 x WT + 10.23 x HT - 5.8 x AGE - 1032</td>
<td>7.48 x WT - 0.42 x HT - 3 x AGE + 844</td>
</tr>
<tr>
<td>M</td>
<td>18-30</td>
<td>11.3 x WT + 16 x HT + 901</td>
<td>15.3 x WT + 679</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>30-60</td>
<td>8.7 x WT + 829</td>
<td>11.6 x WT + 879</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>≥60</td>
<td>13.5 x WT + 487</td>
<td>15.3 x WT + 679</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td>8.7 x WT - 25 x HT + 865</td>
<td>11.6 x WT + 879</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td></td>
<td>66.4730 + 13.7516 x WT + 5.0033 x HT - 6.7550 x AGE</td>
<td>15.3 x WT + 679</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td>665.0955 + 9.5634 x WT + 1.8496 x HT - 4.6756 x AGE</td>
<td>15.3 x WT + 679</td>
<td></td>
<td></td>
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<tr>
<td>M</td>
<td>151-200</td>
<td>25.0-125</td>
<td>88.362 + 4.799 x HT + 13.397 x WT - 5.677 x AGE</td>
<td>15.3 x WT + 679</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td>447.593 + 3.098 x HT + 9.247 x WT - 4.330 x AGE</td>
<td>15.3 x WT + 679</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>30-60</td>
<td>22.8 ± 3.24</td>
<td>0.0592 x WT + 2.48 = MJ/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>30-60</td>
<td>23.3 ± 4.48</td>
<td>0.0407 x WT + 2.90 = MJ/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>30-60</td>
<td>24.6 ± 4.13</td>
<td>0.0563 x WT + 2.15 = MJ/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>30-60</td>
<td>0.0478 x WT + 2.26 x HT - 1.07</td>
<td>0.0478 x WT + 2.26 x HT - 1.07</td>
<td></td>
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</tr>
<tr>
<td>F</td>
<td>334</td>
<td>69.8 ± 6.88</td>
<td>156 ± 9.0</td>
<td>59.1 ± 13.7</td>
<td>4.3 ± 4.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Huang et al.</td>
<td>N= 1088</td>
<td>44.9 ± 12.7</td>
<td>≥35</td>
<td>71.767 - 2.337 x AGE + 257.293 x GENDER + 9.996 x WT + 4.132 x HT + 145.959 x DM</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>279</td>
<td>156 ± 9</td>
<td>78.6 ± 14.8</td>
<td>25.9 ± 4.1</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>759</td>
<td>156 ± 9</td>
<td>85.1 ± 13.1</td>
<td>25.5 ± 4.4</td>
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<tr>
<td>Korth et al.</td>
<td>N= 104</td>
<td>20-70:</td>
<td>154-196:</td>
<td>49.2-135:</td>
<td>17.6-40.9</td>
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<td>174 ± 8.1</td>
<td>78.6 ± 14.8</td>
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<td></td>
</tr>
<tr>
<td>M</td>
<td>50</td>
<td>37.1 ± 15.1</td>
<td>166-96.0</td>
<td>57.2-118</td>
<td>25.9 ± 4.1</td>
</tr>
<tr>
<td>F</td>
<td>54</td>
<td>35.3 ± 15.4</td>
<td>154-182</td>
<td>49.2-135</td>
<td>25.5 ± 4.4</td>
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<tr>
<td>Lazzer et al.</td>
<td>N= 346</td>
<td>20-65:</td>
<td>124 ± 22.6</td>
<td>41.6 ± 6.8</td>
<td>0.048 x WT + 4.655 x HTM - 0.020 x AGE - 3.605 = kJ/d</td>
</tr>
<tr>
<td>M</td>
<td>164</td>
<td>46.3 ± 13.8</td>
<td>170 ± 0.10</td>
<td>106 ± 17.5</td>
<td>41.9 ± 6.5</td>
</tr>
<tr>
<td>F</td>
<td>182</td>
<td>47.8 ± 13.9</td>
<td>160 ± 0.10</td>
<td>106 ± 17.5</td>
<td>41.9 ± 6.5</td>
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<td>Lazzer et al.</td>
<td>N= 7368</td>
<td>18-95:</td>
<td>124 ± 22.6</td>
<td>41.6 ± 6.8</td>
<td>0.042 x WT + 3.619 x HTM - 2.678 = MJ/d</td>
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<tr>
<td>M</td>
<td>299</td>
<td>18-95:</td>
<td>174 ± 8.1</td>
<td>78.6 ± 14.8</td>
<td>25.9 ± 4.1</td>
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<tr>
<td>F</td>
<td>356</td>
<td>18-77:</td>
<td>154 ± 182</td>
<td>49.2 ± 135</td>
<td>25.5 ± 4.4</td>
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<td>Livingston and Kohlstedt</td>
<td>N= 655</td>
<td>20-65:</td>
<td>124 ± 22.6</td>
<td>41.6 ± 6.8</td>
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<td>De Lorenzo et al.</td>
<td>M= 320</td>
<td>18-59:</td>
<td>158-197:</td>
<td>60.7-123:</td>
<td>19.2-39.4</td>
</tr>
<tr>
<td>M</td>
<td>127</td>
<td>158-197:</td>
<td>60.7-123:</td>
<td>19.2-39.4</td>
<td>53.284 x WT + 20.957 x HT - 23.859 x AGE + 487 = kJ/d</td>
</tr>
<tr>
<td>F</td>
<td>193</td>
<td>19-59:</td>
<td>177 ± 6.9</td>
<td>83.8 ± 14.4</td>
<td>26.7 ± 4.3</td>
</tr>
<tr>
<td>M</td>
<td>107</td>
<td>60.8 ± 5.1</td>
<td>173 ± 6.5</td>
<td>78.8 ± 9.7</td>
<td>26.3 ± 3.1</td>
</tr>
<tr>
<td>F</td>
<td>179</td>
<td>67.8 ± 5.7</td>
<td>160 ± 5.5</td>
<td>67.5 ± 10.0</td>
<td>26.4 ± 3.7</td>
</tr>
<tr>
<td>M</td>
<td>251</td>
<td>19-78:</td>
<td>160-201:</td>
<td>58-143:</td>
<td>19-42:</td>
</tr>
<tr>
<td>F</td>
<td>247</td>
<td>20-76:</td>
<td>146-186:</td>
<td>46-120:</td>
<td>17-42:</td>
</tr>
<tr>
<td>Müller et al.</td>
<td>N= 2528</td>
<td>5-91:</td>
<td>164 ± 6.3</td>
<td>72 ± 13.9</td>
<td>27.8 ± 5.1</td>
</tr>
<tr>
<td></td>
<td>(1027 M, 1501 F)</td>
<td>44.6 ± 14.0</td>
<td>164 ± 6.3</td>
<td>72 ± 13.9</td>
<td>27.8 ± 5.1</td>
</tr>
</tbody>
</table>

| M         | 127      | 158-197: | 60.7-123: | 19.2-39.4 | 53.284 x WT + 20.957 x HT - 23.859 x AGE + 487 = kJ/d |
| F         | 193      | 19-59: | 177 ± 6.9 | 83.8 ± 14.4 | 26.7 ± 4.3 |
| M         | 107      | 60.8 ± 5.1 | 173 ± 6.5 | 78.8 ± 9.7 | 26.3 ± 3.1 |
| F         | 179      | 67.8 ± 5.7 | 160 ± 5.5 | 67.5 ± 10.0 | 26.4 ± 3.7 |
| M         | 251      | 19-78: | 160-201: | 58-143: | 19-42: |
| F         | 247      | 20-76: | 146-186: | 46-120: | 17-42: |

Equation for all BMI 0.047 x WT + 1.009 x GENDER - 0.01452 x AGE + 3.21 = MJ/d
Equation for BMI 25-30 0.04507 x WT + 1.006 x GENDER - 0.01553 x AGE + 3.407 = MJ/d
Equation for BMI≥30
<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>M range</th>
<th>M mean ± SD</th>
<th>F range</th>
<th>F mean ± SD</th>
<th>REE (MJ/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owen et al.</td>
<td>104</td>
<td>18-82:</td>
<td>163-188:</td>
<td>59.8-171:</td>
<td>20.4-58.7</td>
<td>0.05 x WT + 1.103 x GENDER - 0.01586 x AGE + 2.924 = MJ/d</td>
</tr>
<tr>
<td></td>
<td></td>
<td>38 ± 15.6</td>
<td>175 ± 6.9</td>
<td>86.6 ± 23.8</td>
<td>28.2 ± 7.5</td>
<td>879 + 10.2 x WT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>44</td>
<td>18-65:</td>
<td>43.1-143:</td>
<td>18.2-49.6</td>
<td>795 + 7.18 x WT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35 ± 12.2</td>
<td>164 ± 6.8</td>
<td>74.9 ± 24.6</td>
<td>27.8 ± 8.6</td>
<td></td>
</tr>
<tr>
<td>Schofield</td>
<td>4814</td>
<td>18-30</td>
<td>30-60</td>
<td>≥60</td>
<td>163-188:</td>
<td>0.063 x WT + 2.896 = MJ/d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>41 ± 12</td>
<td>0.063 x WT - 0.042 x HTM + 2.953 = MJ/d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>95</td>
<td>0.062 x WT + 2.036 = MJ/d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>42 ± 12</td>
<td>0.057 x WT + 1.148 x HTM + 0.411 = MJ/d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>42 ± 12</td>
<td>0.048 x WT + 3.653 = MJ/d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>42 ± 12</td>
<td>0.048 x WT - 0.011 x HTM + 3.67 = MJ/d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>42 ± 12</td>
<td>0.034 x WT + 3.538 = MJ/d</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>42 ± 12</td>
<td>0.034 x WT + 0.006 x HTM + 3.53 = MJ/d</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>42 ± 12</td>
<td>0.049 x WT + 2.459 = MJ/d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>42 ± 12</td>
<td>0.038 x WT + 4.068 x HTM - 3.491 = MJ/d</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>42 ± 12</td>
<td>0.038 x WT + 2.755 = MJ/d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>42 ± 12</td>
<td>0.033 x WT + 1.917 x HTM + 0.074 = MJ/d</td>
</tr>
<tr>
<td>Weijs et al.</td>
<td>136</td>
<td>18-30</td>
<td>30-60</td>
<td>≥60</td>
<td>163-188:</td>
<td>16.790 x WT + 4.531 x HT + 0.169 x AGE - 420.492</td>
</tr>
<tr>
<td>(abstract)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>42 ± 12</td>
<td>12.753 x WT + 3.869 x HT - 1.489 x AGE + 13.150</td>
</tr>
</tbody>
</table>

1REE in kcal/d unless described in MJ/d or kJ/d
2WT, weight in kg; HT, height in cm; HTM, height in meters; FFM, fat-free mass in kg; FM, fat mass in kg; AGE, age in y; GENDER (M = 1, F = 0); REE, resting energy expenditure in kcal/d; DM, diabetes mellitus
3Air-displacement plethysmography was selected over other available body-composition methods because it was used for assessment in the present study
4People on whom the development of the equation is based
5People on whom the cross-validation is tested
Table 1B: Predictive equations for resting energy expenditure using age, FFM, FM, BMI and gender.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Reference population</th>
<th>Gender</th>
<th>N</th>
<th>Age in y</th>
<th>HT (cm)</th>
<th>WT (kg)</th>
<th>BMI (kg/m²)</th>
<th>Predictive equations for estimating REE in kcal/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bernstein et al.</td>
<td>Na 202</td>
<td>M</td>
<td>46</td>
<td>40.4 ± 11.4</td>
<td>177 ± 8.8</td>
<td>60.6-204</td>
<td>19.02 x FFM + 3.71 x FM - 1.55 x AGE + 236.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>154</td>
<td>39 ± 12.0</td>
<td>154 ± 6.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huang et al.</td>
<td>N=108</td>
<td>M</td>
<td>279</td>
<td>44.9 ± 12.7</td>
<td></td>
<td>235</td>
<td>14.11 x FFM - 9.367 x FM - 1.615 x AGE + 220.863 x GENDER - 521.995</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Johnstone et al.</td>
<td>N=150</td>
<td>M</td>
<td>43</td>
<td>21.6-4</td>
<td></td>
<td>16.7-93</td>
<td>1613 + 31.6 x FM + 50.2 x FFM + 12.2 x AGE = KJ/d</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>107</td>
<td>42 ± 11.4</td>
<td>163 ± 6.0</td>
<td>63.3 ± 16.5</td>
<td>17.6-40.9</td>
<td>108.1 x FFM + 1231 = kJ/d</td>
</tr>
<tr>
<td>Korth et al.</td>
<td>N=104</td>
<td>M</td>
<td>50</td>
<td>37.1 ± 13.1</td>
<td>156±196</td>
<td>25.9 ± 4.1</td>
<td>20.7±5.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>54</td>
<td>35.3 ± 15.4</td>
<td>154±182</td>
<td>25.3 ± 4.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lazer et al. 2007</td>
<td>N=346</td>
<td>M</td>
<td>164</td>
<td>20.65</td>
<td></td>
<td>0.001 x FFM + 0.049 x FM - 0.019 x AGE - 2.134 = MJ/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>182</td>
<td>19.60</td>
<td></td>
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<tr>
<td>Lazer et al. 2010</td>
<td>N=755</td>
<td>M</td>
<td>200</td>
<td>46.3 ± 13.8</td>
<td>170 ± 10</td>
<td></td>
<td>41.6 ± 6.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>285</td>
<td>47.3 ± 13.3</td>
<td>160 ± 10</td>
<td>108±17.5</td>
<td>41.9 ± 6.5</td>
<td></td>
</tr>
<tr>
<td>Mifflin et al.</td>
<td>N=495</td>
<td>M</td>
<td>251</td>
<td>19.78</td>
<td>160±201</td>
<td>56.48</td>
<td>19.422</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>247</td>
<td>20.75</td>
<td>146±185</td>
<td>46.20</td>
<td>17.42</td>
<td></td>
</tr>
<tr>
<td>Müller et al.</td>
<td>N=2538</td>
<td>M</td>
<td>1027</td>
<td>44.2 ± 17.3</td>
<td>*170 ± 20.0</td>
<td>27.1 ± 7.7</td>
<td>0.05182 x FFM + 0.04036 x FM - 0.069 x GENDER - 0.01181 x AGE + 1.992 = MJ/d</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>1801</td>
<td>**44.1 ± 17.4</td>
<td>**170 ± 9.8</td>
<td>**77.2 ± 21.4</td>
<td>**26.8 ± 7.1</td>
<td></td>
</tr>
<tr>
<td>Owen et al.</td>
<td>N=104</td>
<td>M</td>
<td>50</td>
<td>18.82</td>
<td>163±188</td>
<td>10.4±58.7</td>
<td>290 ± 12.3 x FFM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>44</td>
<td>18.65</td>
<td>150±180</td>
<td>86.6 ± 23.8</td>
<td>26.2 ± 7.5</td>
<td></td>
</tr>
</tbody>
</table>

*REE in kcal/d unless described in MJ or kJ/d
*WT, weight in kg; HT, height in cm; FFM, fat-free mass in kg; FM, fat mass in kg; AGE, age in y; GENDER (M = 1, F = 0); REE, resting energy expenditure in kcal/d
Air-displacement plethysmography was selected over other available body-composition methods because it was used for assessment in the present study
People on whom the development of the equation is based
People on whom the cross-validation is tested
Statistics

The accuracy of the REE equations was evaluated by the percentage accurate predictions. A prediction by an equation was accurate when the calculated REE deviated less than 10% from the measured REE by IC.48

A prediction <90% of the REE measured was classified as an underestimation, and a prediction >110% of the REE measured by IC was classified as an overestimation. The mean REE difference between predicted and measured values (bias), the root mean squared prediction error (RMSE), were both calculated with Microsoft Office Excel 2010; Amsterdam, The Netherlands, Bland-Altman plots and the concordance correlation coefficient (CCC), both calculated with MedCalc software (version 12.1.1 Mariakerke, Belgium) were used to indicate how well the model predicted in the data set (Appendix I).52 53 Data were also analyzed by using SPSS (PASW 18.0.0, SPSS Inc., Chicago, IL)

Linear regression analyses were used to generate a prediction model to predict REE. The following variables were used in the ENTER selection procedure: age, weight, height, FFM and FM and/or gender. The prediction model omitted variables until all variables contributed to the prediction of the effect variable.51 53 54 The assumption of normality of the outcome variable REE and continuous determinants age, weight, height, FFM and FM and/or gender was tested by evaluating P-P plots of residuals.52

In this thesis four equations were developed. The first two developed equations were based on the following variables: weight, age, height and/or gender. A third and fourth equation were developed based on age, height, gender, FFM and FM. Subsequently, the new equations were evaluated as described earlier.
Results

81 subjects were included in this study, 25 were male and 56 were female. Table 2 shows body composition, anthropometric and REE data of all subjects and for male and female separately. Males differ significantly from women on weight, height, FFM, FM and REE IC. The mean age was 61 years and the mean BMI was 33.2 kg/m².

Table 2:
Subject characteristics: body composition, anthropometric data and resting energy expenditure.

<table>
<thead>
<tr>
<th></th>
<th>Total (N=81)</th>
<th>Men (n=25)</th>
<th>Women (n=56)</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>61.3 ± 5.23</td>
<td>61.2 ± 5.56</td>
<td>61.4 ± 5.13</td>
<td>0.892</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>95.3 ± 14.2</td>
<td>103 ± 15.0</td>
<td>91.8 ± 12.4</td>
<td>0.001*</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.69 ± 0.08</td>
<td>1.77 ± 0.07</td>
<td>1.66 ± 0.06</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>33.2 ± 4.42</td>
<td>32.9 ± 4.98</td>
<td>33.3 ± 4.19</td>
<td>0.737</td>
</tr>
<tr>
<td>FM^b (kg)</td>
<td>42.2 ± 10.5</td>
<td>37.3 ± 11.3</td>
<td>44.4 ± 9.38</td>
<td>0.004*</td>
</tr>
<tr>
<td>FM^b (%)</td>
<td>44.2 ± 7.86</td>
<td>35.6 ± 5.82</td>
<td>48.1 ± 5.11</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>FFM^b (kg)</td>
<td>53.0 ± 10.4</td>
<td>65.8 ± 6.48</td>
<td>47.3 ± 5.51</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>FFM^b (%)</td>
<td>48.1 ± 5.11</td>
<td>35.6 ± 5.82</td>
<td>48.1 ± 5.11</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>REE IC (kcal)</td>
<td>1781 ± 305</td>
<td>1223-2804</td>
<td>1663 ± 223</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

*P-value for difference between men, women and using independent samples t-test.

Newly developed equation

In this thesis the current equations from the literature were evaluated. This can be seen in Table 1A and B. In Table 3A and 3B the evaluation of the current equations from literature and the newly developed equations will be described. By using linear regression techniques four new equations were developed based on the 81 subjects (Appendix II):
**Klaver-Rootjes equation:**  
$$257.990 + (208.508 \times \text{GENDER}) - (5.398 \times \text{AGE}) + (11.017 \times \text{WT}) + (436.796 \times \text{HT})$$  
r=0.793; $R^2=0.628$

**Klaver-Rootjes FFM equation:**  
$$573.969 + (38.139 \times \text{GENDER}) - (4.149 \times \text{AGE}) + (7.418 \times \text{FM}) + (21.434 \times \text{FFM})$$  
r=0.809; $R^2=0.655$

**Klaver-Rootjes Gender equation**

**Male:**  
$$1434.934 - (6.459 \times \text{AGE}) + (11.076 \times \text{WT}) - (76.819 \times \text{HT})$$  
r=0.583; $R^2=0.340$

**Female:**  
$$-307.994 - (4.227 \times \text{AGE}) + (10.673 \times \text{WT}) + (753.495 \times \text{HT})$$  
r=0.727; $R^2=0.529$

**Klaver-Rootjes Gender FFM equation**

**Male:**  
$$972.405 - (7.512 \times \text{AGE}) + (7.184 \times \text{FM}) + (19.220 \times \text{FFM})$$  
r=0.609; $R^2=0.371$

**Female:**  
$$318.565 - (1.571 \times \text{AGE}) + (7.047 \times \text{FM}) + (23.837 \times \text{FFM})$$  
r=0.755; $R^2=0.570$

WT, weight in kg; HT, height in meters; FFM, fat-free mass in kg; FM, fat mass in kg; AGE, age in years; GENDER (male=1, female=0); REE, resting energy expenditure in kcal/d.

Results on accuracy of the predictive equations are shown in Table 3A and 3B. Data are displayed as: REE in kcal/d, bias in kcal/d and percentage, RMSE in kcal/d and percentage of accurate-, under- and overpredictions.
Table 3A: Evaluation of resting energy expenditure (REE) predictive equations based on weight (WT) and height (HT) with bias, root mean squared prediction error (RMSE) and percentage accurate prediction.

<table>
<thead>
<tr>
<th>Predictive equation</th>
<th>Mean REE&lt;sup&gt;a&lt;/sup&gt;</th>
<th>SD</th>
<th>Bias&lt;sup&gt;b&lt;/sup&gt;</th>
<th>RMSE&lt;sup&gt;c&lt;/sup&gt;</th>
<th>CCC&lt;sup&gt;d&lt;/sup&gt;</th>
<th>Accurate predictions&lt;sup&gt;e&lt;/sup&gt;</th>
<th>Under predictions&lt;sup&gt;f&lt;/sup&gt;</th>
<th>Over predictions&lt;sup&gt;g&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>REE IC</td>
<td>1781</td>
<td>305</td>
<td>-320 ± 227 -16.6</td>
<td>392</td>
<td>0.294</td>
<td>22.2</td>
<td>76.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Bernstein et al. 32</td>
<td>1461</td>
<td>152</td>
<td></td>
<td>272</td>
<td>0.634</td>
<td>43.2</td>
<td>1.2</td>
<td>55.6</td>
</tr>
<tr>
<td>FAO/WHO/UNU 1985&lt;sup&gt;33&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td>1972</td>
<td>0.673</td>
<td>49.4</td>
<td>2.5</td>
<td>48.1</td>
</tr>
<tr>
<td>18-30y</td>
<td>1948</td>
<td>283</td>
<td>167 ± 194 10.4</td>
<td>255</td>
<td>0.747</td>
<td>64.2</td>
<td>16.0</td>
<td>19.8</td>
</tr>
<tr>
<td>30-60y</td>
<td>1766</td>
<td>246</td>
<td>-15.4 ± 197 0.2</td>
<td>196</td>
<td>0.736</td>
<td>63.0</td>
<td>19.8</td>
<td>14.0</td>
</tr>
<tr>
<td>30-60y WT and HT</td>
<td>1750</td>
<td>232</td>
<td>-31 ± 195 0.6</td>
<td>196</td>
<td>0.736</td>
<td>63.0</td>
<td>19.8</td>
<td>14.0</td>
</tr>
<tr>
<td>≥60y</td>
<td>1658</td>
<td>214</td>
<td>123 ± 194 -5.8</td>
<td>229</td>
<td>0.656</td>
<td>56.8</td>
<td>35.8</td>
<td>7.4</td>
</tr>
<tr>
<td>≥60y WT and HT</td>
<td>1672</td>
<td>181</td>
<td>-109 ± 204 -4.8</td>
<td>230</td>
<td>0.609</td>
<td>63.0</td>
<td>29.6</td>
<td>7.4</td>
</tr>
<tr>
<td>HB 1919&lt;sup&gt;34&lt;/sup&gt;</td>
<td>1684</td>
<td>246</td>
<td>-96.6 ± 191 -4.5</td>
<td>213</td>
<td>0.718</td>
<td>59.3</td>
<td>33.3</td>
<td>7.4</td>
</tr>
<tr>
<td>HB by Roza et al. 1984&lt;sup&gt;19&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td>1677</td>
<td>0.720</td>
<td>59.3</td>
<td>34.6</td>
<td>6.2</td>
</tr>
<tr>
<td>Henry&lt;sup&gt;35&lt;/sup&gt;</td>
<td>1730</td>
<td>265</td>
<td>-51.4 ± 198 2.0</td>
<td>203</td>
<td>0.749</td>
<td>63.0</td>
<td>24.7</td>
<td>12.3</td>
</tr>
<tr>
<td>30-60y WT and HT</td>
<td>1702</td>
<td>240</td>
<td>-79.4 ± 192 3.5</td>
<td>206</td>
<td>0.725</td>
<td>59.3</td>
<td>30.9</td>
<td>9.9</td>
</tr>
<tr>
<td>≥60y</td>
<td>1623</td>
<td>241</td>
<td>-158 ± 193 -8.0</td>
<td>248</td>
<td>0.646</td>
<td>48.1</td>
<td>49.4</td>
<td>2.5</td>
</tr>
<tr>
<td>≥60y WT and HT</td>
<td>1595</td>
<td>237</td>
<td>-186 ± 191 -9.6</td>
<td>266</td>
<td>0.611</td>
<td>42.0</td>
<td>55.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Huang et al. 36</td>
<td>1660</td>
<td>242</td>
<td>-121 ± 188 5.9</td>
<td>222</td>
<td>0.699</td>
<td>55.6</td>
<td>39.5</td>
<td>4.9</td>
</tr>
<tr>
<td>Korth et al.&lt;sup&gt;37&lt;/sup&gt;</td>
<td>1750</td>
<td>273</td>
<td>-31 ± 192 0.9</td>
<td>193</td>
<td>0.776</td>
<td>72.8</td>
<td>16.0</td>
<td>11.1</td>
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<tr>
<td>Klaver-Rootjes</td>
<td>1781</td>
<td>242</td>
<td>-0.06 ± 186 1.1</td>
<td>185</td>
<td>0.772</td>
<td>67.9</td>
<td>12.3</td>
<td>19.8</td>
</tr>
<tr>
<td>Klaver-Rootjes Gender</td>
<td>1781</td>
<td>242</td>
<td>0.04 ± 184 1.0</td>
<td>183</td>
<td>0.776</td>
<td>69.0</td>
<td>11.1</td>
<td>19.8</td>
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<tr>
<td>Lazzer et al. 2007&lt;sup&gt;38&lt;/sup&gt;</td>
<td>1804</td>
<td>216</td>
<td>23.1 ± 196 2.6</td>
<td>196</td>
<td>0.722</td>
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<tr>
<td>Lazzer et al. 2010&lt;sup&gt;13&lt;/sup&gt;</td>
<td>843</td>
<td>159</td>
<td>-938 ± 223 -52.4</td>
<td>964</td>
<td>0.068</td>
<td>0.0</td>
<td>100.0</td>
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<tr>
<td>Livingston and Kohlstadt&lt;sup&gt;40&lt;/sup&gt;</td>
<td>1569</td>
<td>202</td>
<td>-212 ± 194 10.9</td>
<td>286</td>
<td>0.537</td>
<td>39.5</td>
<td>58.0</td>
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<td>De Lorenzo et al.&lt;sup&gt;41&lt;/sup&gt;</td>
<td>1729</td>
<td>234</td>
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<td>Lührmann et al.&lt;sup&gt;42&lt;/sup&gt;</td>
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<td>217</td>
<td>-54.3 ± 191 1.9</td>
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<td>Mifflin et al. 30</td>
<td>1599</td>
<td>225</td>
<td>-182 ± 187 9.3</td>
<td>260</td>
<td>0.613</td>
<td>44.4</td>
<td>51.9</td>
<td>3.7</td>
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<td>Model</td>
<td>Sample Size</td>
<td>REE Predicted (Mean ± SD)</td>
<td>REE Measured (Mean ± SD)</td>
<td>RMSE</td>
<td>CCC</td>
<td>Percentage 10% REE Pred.</td>
<td>Percentage &lt;10% REE Pred.</td>
<td>Percentage &gt;10% REE Pred.</td>
</tr>
<tr>
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<td>--------------</td>
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<tr>
<td>Müller et al., 1993</td>
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<td>-82.0 ± 188, -3.6</td>
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<td>BMI ≥30</td>
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<td>-94.8 ± 188, -4.4</td>
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<td>32.1, 6.2</td>
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<td>1969</td>
<td>188 ± 195, 11.8</td>
<td>270, 0.634, 44.4</td>
<td>1.2, 54.3</td>
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<td>18-30y</td>
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<td>3.7, 46.9</td>
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<tr>
<td>30-60y</td>
<td>1735</td>
<td>-46.2 ± 199, -1.6</td>
<td>203, 0.735, 63.0</td>
<td>22.2, 14.8</td>
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<td></td>
</tr>
<tr>
<td>30-60y WT and HT</td>
<td>1735</td>
<td>-46.1 ± 199, -1.6</td>
<td>203, 0.735, 63.0</td>
<td>22.2, 14.8</td>
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<td>≥60y</td>
<td>1586</td>
<td>-195 ± 197, -9.8</td>
<td>277, 0.543, 43.2</td>
<td>55.6, 1.2</td>
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<tr>
<td>≥60y WT and HT</td>
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<td>-180 ± 196, -9.0</td>
<td>265, 0.568, 49.4</td>
<td>48.1, 2.5</td>
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<tr>
<td>Weijs et al., 2010</td>
<td>1854</td>
<td>73.5 ± 194, 5.2</td>
<td>206, 0.748, 64.2</td>
<td>6.2, 29.6</td>
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</tbody>
</table>

1 REE measured by IC
2 Mean systematic error and standard deviation between REE predicted with an equation and REE measured by IC
3 RMSE, root mean squared error
4 CCC, concordance correlation coefficient
5 Percentage of subjects predicted within 10% REE measured
6 Percentage of subjects predicted <10% REE measured
7 Percentage of subjects predicted >10% REE measured
Table 3B: Evaluation of resting energy expenditure (REE) predictive equations based on fat-free mass (FFM) and fat mass (FM) with bias, root mean squared prediction error (RMSE) and percentage accurate prediction.

<table>
<thead>
<tr>
<th>Predictive formula</th>
<th>Mean REE</th>
<th>SD</th>
<th>Bias</th>
<th>RMSE</th>
<th>CCC</th>
<th>Accurate predictions</th>
<th>Under predictions</th>
<th>Over predictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>REE IC</td>
<td>Kcal/d</td>
<td></td>
<td></td>
<td>Kcal/d</td>
<td></td>
<td>%</td>
<td></td>
<td></td>
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<tr>
<td>Bernstein et al. 32</td>
<td>1781</td>
<td>305</td>
<td>-474 ± 187</td>
<td>-26.0</td>
<td>509</td>
<td>0.272</td>
<td>2.5</td>
<td>97.5</td>
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<tr>
<td>Huang et al. 36</td>
<td>1641</td>
<td>242</td>
<td>-140 ± 185</td>
<td>-7.0</td>
<td>231</td>
<td>0.684</td>
<td>55.6</td>
<td>40.7</td>
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<tr>
<td>Johnstone et al. 47</td>
<td>1669</td>
<td>234</td>
<td>-112 ± 180</td>
<td>-5.4</td>
<td>211</td>
<td>0.719</td>
<td>65.4</td>
<td>30.9</td>
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<tr>
<td>Klaver-Rootjes</td>
<td>1781</td>
<td>247</td>
<td>0.00 ± 179</td>
<td>0.0</td>
<td>178</td>
<td>0.792</td>
<td>70.4</td>
<td>12.3</td>
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<tr>
<td>Klaver-Rootjes Gender</td>
<td>1781</td>
<td>247</td>
<td>0.03 ± 178</td>
<td>1.0</td>
<td>183</td>
<td>0.794</td>
<td>69.0</td>
<td>12.3</td>
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<tr>
<td>Korth et al. 37</td>
<td>1664</td>
<td>268</td>
<td>-117 ± 197</td>
<td>-5.9</td>
<td>228</td>
<td>0.704</td>
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<td>Lazzer et al. 2007</td>
<td>1401</td>
<td>376</td>
<td>-380 ± 542</td>
<td>-18.3</td>
<td>659</td>
<td>-0.156</td>
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<td>44.4</td>
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<tr>
<td>Lazzer et al. 2010</td>
<td>890</td>
<td>201</td>
<td>-891 ± 196</td>
<td>-50.0</td>
<td>912</td>
<td>0.101</td>
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<td>100.0</td>
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<tr>
<td>Mifflin et al. 20</td>
<td>1458</td>
<td>204</td>
<td>-323 ± 197</td>
<td>-17.3</td>
<td>378</td>
<td>0.398</td>
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<td>86.4</td>
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<tr>
<td>Müller et al. 43</td>
<td>1671</td>
<td>222</td>
<td>-110 ± 186</td>
<td>-5.1</td>
<td>215</td>
<td>0.697</td>
<td>64.2</td>
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<td>BMI 25-30</td>
<td>1615</td>
<td>189</td>
<td>-166 ± 195</td>
<td>-8.2</td>
<td>255</td>
<td>0.579</td>
<td>48.1</td>
<td>46.9</td>
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<tr>
<td>BMI ≥30</td>
<td>1654</td>
<td>229</td>
<td>127 ± 184</td>
<td>-6.2</td>
<td>223</td>
<td>0.689</td>
<td>58.0</td>
<td>38.3</td>
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<tr>
<td>Owen et al. 44</td>
<td>1418</td>
<td>258</td>
<td>363 ± 202</td>
<td>-19.9</td>
<td>415</td>
<td>0.404</td>
<td>14.8</td>
<td>84.0</td>
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</table>

1REE measured by IC  
2Mean systematic error and standard deviation between REE predicted with an equation and REE measured by IC  
3RMSE, root mean squared error  
4CCC, concordance correlation coefficient  
5Percentage of subjects predicted within 10% REE measured  
6Percentage of subjects predicted <10% REE measured  
7Percentage of subjects predicted >10% REE measured

The percentage of accurate predictions are shown in Figure 1A and 1B. The predictive equations with the most accurate predictions are: Korth et al. 37 (72.8%) and the newly developed equations: Klaver-Rootjes Gender (69%) and Klaver-Rootjes (67.9%). Bernstein et al. 32 showed in 22.2% of the subjects an accurate prediction. The highest accurate predictions for equations based on FFM and FM are: Klaver Rootjes (70.4%) and Klaver-Rootjes Gender (69%). It can be seen in Table 3A and 3B, from 81 subjects had Lazzer et al. 2010 13 none accurate predictions.
In Figure 2A and 2B RMSE in kcal/d between predicted and measured REE are shown. These equations are ranked from smallest to highest deviation. Scores in RMSE closer to 0 are more propitious. The RMSE can be regarded as the average deviation from the measured REE by IC. Klaver-Rootjes Gender and Klaver-Rootjes showed the smallest RMSE for equations based on weight and height in Figure 2A, respectively the RMSE was 183 and 185 kcal. For equations based on FFM and FM the smallest RMSE were Klaver-Rootjes (178) and Klaver-Rootjes Gender (183).

The CCC of the REE equations are shown in Figure 3A and 3B. If the CCC value is closer to 1, the stronger the correlation between predicted and measured REE. The closest value to 1 were from the following equations based on weight and/or height: the newly developed equation of Klaver-Rootjes Gender (0.776), Korth et al.37 (0.776) and the newly developed equation of Klaver-Rootjes (0.772).

The closest value to 1 for the predictive equations based on FFM and FM were: Klaver-Rootjes Gender (0.794) and Klaver-Rootjes (0.792).

The predictive equations with the highest underprediction were Bernstein et al.32 (76.5%) and Lazzer et al.2010 (100%). The highest overprediction were FAO/WHO/UNU33 18-30 years (55.6%) and Schofield45 18-30 years (54.3%). The $R^2$ is the explained variance of the measured REE by IC which is comparable to the $R^2$ of the current equations that are commonly used in dietary practice.

Figures 4A-F show the deviation between REE measured by IC and predicted by an equation. The difference of REE measured and REE predicted against their mean is displayed. Because the Harris and Benedict equation of 191934 and 198419 are often used in dietary practice, the accuracy of the predictive equations is compared by using Bland-Altman plots. When comparing the Klaver-Rootjes equations with Harris and Benedict equations of 191934 and 198419 the mean REE estimated of the Harris and Benedict equation of 191934 and 198419 shows an underprediction compared to measured REE (-96.6 and -104.4 kcal/d resp.). Figure 4A and 4C show that approximately 95% of the subjects have a deviation of -364 to +364 kcal/d (Klaver-Rootjes Gender) and -361 to +361 kcal/d (Klaver-Rootjes) from the mean REE measured. The values for the other newly developed equations of Figure 4B (Klaver-Rootjes Gender FFM) and Figure 4D (Klaver-Rootjes FFM) are as follows: -351 to +351 kcal/d and -349 to +349 kcal/d. The distance between the limits of agreement are smaller for Klaver-Rootjes FFM and Klaver-Rootjes Gender FFM equations and the average bias is 0, which is propitious.
Figure 1A: Percentage accurately predicted resting energy expenditure (REE) within 10% of REE measured for the different equations based on weight (WT) and height (HT). Lazzer 2010 is not included as a result of the incorrect outcome.

Figure 1B: Percentage accurately predicted resting energy expenditure (REE) within 10% of REE measured for the different equations based on fat-free mass (FFM) and fat mass (FM). Lazzer 2010 is not included as a result of the incorrect outcome.
Figure 2A: Root mean squared error (RMSE) between predicted and measured resting energy expenditure (REE) in kcal/d. Lazzer 2010 is not included as a result of the incorrect outcome.

Figure 2B: Root mean squared error (RMSE) between predicted and measured resting energy expenditure (REE) in kcal/d. Lazzer 2010 is not included as a result of the incorrect outcome.
Figure 3A: Concordance Correlation Coefficient (CCC) of the resting energy expenditure (REE) equations. Lazzer 2010 is not included as a result of the incorrect outcome.

Figure 3B: Concordance Correlation Coefficient (CCC) of the resting energy expenditure (REE) equations based on fat-free mass (FFM) and fat mass (FM). Lazzer 2010 is not included as a result of the incorrect outcome.
Figure 4A: Klaver-Rootjes Gender equation

Figure 4B: Klaver-Rootjes Gender FFM equation

Figure 4C: Klaver-Rootjes equation

Figure 4D: Klaver-Rootjes FFM equation

Figure 4E: Harris and Benedict 1919 equation

Figure 4F: Harris and Benedict 1984 equation

Figure 4A-F: Bland-Altman plots of the resting energy expenditure (REE) predicted compared to REE measured.
Discussion

The current equations and newly developed predictive equation for estimating REE in overweight people over 55 years of age is evaluated in this study. It can be concluded from the results in this study, Korth et al.\textsuperscript{37} based on weight and height is the most accurate equation to estimate REE in overweight people over 55 years of age. Based on FFM and FM, the Klaver-Rootjes Gender equation is the most accurate equation.

The expectations about the equations from literature on the subject, for example the Harris and Benedict equation\textsuperscript{19,34}, overestimated the REE in overweight people over 55 years of age. The current equations for estimating REE are based on a younger population >18 years of age in comparison with the subjects in this study. The overprediction might be argued as follows: the body composition during aging changes, FM increases while FFM decreases. After 20-30 years of age FFM decreases every decade with 2-3\%.\textsuperscript{24} Other factors might have influence on decreasing FFM during aging: such as hormones.\textsuperscript{26} Decreased FFM is responsible for a lower REE with increasing age.\textsuperscript{12} The REE in adults over 18 years of age might be estimated higher. The body composition of adults over 18 years of age consists of relatively more FFM in comparison with the subjects over 55 years of age in this study. However, this study shows that the REE of nearly 30\% of the subjects were underestimated by using Harris and Benedict 1919\textsuperscript{34} and 1984\textsuperscript{19} equation. During aging people become smaller. Theoretically, if a smaller height is filled in an equation, the estimated REE will be lower. No literature of this topic is available.

From literature, it is expected that FFM is an accurate predictor of REE.\textsuperscript{57,58} In this study the newly developed equations with the highest value of accurate prediction based on weight and height and based on FFM and FM are nearly similar. In practice weight and height equations are more workable, less expensive and take less time to estimate REE in subjects. For equations that include FFM and FM measurement equipment is necessary. In dietary practice skin fold measurements or bioelectrical impedance analysis (BIA) are often used to evaluate body composition. These data can be used to estimate REE with an equation using FFM and FM to set up a hypo caloric diet. However, this study used the BodPod system to measure FFM and FM. The accuracy of the BodPod system is high compared to devices used in practice like skin folds or BIA. Using skin folds or BIA cause more bias and therefore measurements are less accurate. The estimation of REE using FFM and FM might be less accurate in skin fold measurements.
The equations based on weight and height are sufficient to estimate REE in comparison with the equations based on FFM and FM for people over 55 years of age. These equations are more likely to be used in dietary practice. Measurement equipment such as a scale and a length meter can measure weight and height. In dietary practice REE can be predicted by filling in these variables in the equation.59

After statistical analyses it can be concluded the Klaver-Rootjes equations (gender and/or FFM) seems to be accurate in predicting REE. The values for accurate predictions of the Klaver-Rootjes equations (gender and/or FFM) are ranged 67.9-70.4%. This roughly means that REE is still under- or overestimated in 30% of the subjects. The RMSE of the Klaver-Rootjes equations (gender and/or FFM) is ranged 178-183 kcal/day. For example: if a dietician advises a hypo caloric diet (-600 kcal) calculated by Klaver-Rootjes equation (gender and/or FFM), it on average differs 178-183 kcal/day compared to measured REE by IC. With a dietary advice for example 1700 kcal/day (PAL*REE minus 600 kcal) minus or plus the RMSE (178-183 kcal/day) individual subjects might still lose weight.

The Harris and Benedict equation 191934 and 198419 gives a value for RMSE of respectively: 213-216 kcal/day. The difference in individual advice for a hypo caloric diet (-600 kcal) between the Harris and Benedict equation 191934 and 198419 and the Klaver-Rootjes equations is nearly the same. The values of accurate prediction of the Klaver-Rootjes equations are between 67.9-70.4%, for the Harris and Benedict equation is this value 59.3%.

Cross-validation is needed to see if the Klaver-Rootjes equations still has an accurate prediction if tested on other populations. The Klaver-Rootjes equations score also higher than equations which are often used in practice. The Klaver-Rootjes equations are based on the 81 subjects included in this study. The newly developed equations have to be validated on a similar population with a BMI of ≥28 kg/m² and subjects over 55 years of age. Nevertheless, after cross-validation values of accurate prediction of Klaver-Rootjes equations might not be as high as 67.9-70.4% due to the population which the Klaver-Rootjes equations are based on.

Another weak point of this thesis is the different measurement protocols of the several weight loss trials which we obtained our data from. Within the baseline measurements the frequency of the BodPod measurements were sometimes performed once, twice or three times. Although, a strong point of this thesis is that the BodPod is known as one of the most accurate measurement equipments. With the IC, the steady state period differ between the several weight loss trials used in this study. However, in an article from Reeves et al. the accuracy of the measurement of IC cannot be
influenced by a different steady state period.\textsuperscript{51}

The sober period before measurement is different within the weight loss trials: 3-5 hours. Therefore a strict selection procedure of the subjects is used. If subjects eat 3 hours, drink 1 hour or have been physically active 14 hours prior to the measurement, RQ was higher than 1 from IC data are invalid and subjects were excluded.

In conclusion, the equations from Korth et al.\textsuperscript{37}, Klaver-Rootjes, and Klaver-Rootjes Gender predicted REE most accurately in this study. To evaluate whether the Klaver-Rootjes equation is accurate in another overweight population, cross-validation is necessary.
Recommendations

This study recommends dieticians to use predictive equations based on weight and/or height in dietary practice to estimate REE in people over 55 years of age. Weight and/or height equations are more workable, less expensive and take less time compared to equations based on FFM and FM. Furthermore, accuracy of the prediction of REE is not improved by using these FFM and FM equations. Equations from Korth et al.\textsuperscript{37} and the newly developed equations of Klaver-Rootjes and Klaver-Rootjes Gender predicted REE most accurately in this study, although cross-validation of the Klaver-Rootjes equations is necessary and will probably lead to less accurate predictions. The equation of Korth et al.\textsuperscript{37} is not very well known in dietary practice.

Equations of Harris and Benedict 1984\textsuperscript{19}, FAO/WHO/UNU 1985\textsuperscript{33} and Schofield\textsuperscript{45} are the most commonly used equations in dietary practice. In this study, the equation of Harris and Benedict 1984\textsuperscript{19} and Schofield\textsuperscript{45} does not have the best accuracy for estimating REE in people over 55 years of age. However, based on our results, it is advisable to use the equation of FAO/WHO/UNU 1985\textsuperscript{33} 30-60 years based on weight. The value of accurate prediction of the FAO/WHO/UNU 1985\textsuperscript{33} equation 30-60 years based on weight is 64.2%. In 35.8% of the people there still will be an under- or overestimation. Therefore, in dietary practice it is advisable to monitor weight loss to recalculate REE and to adjust dietary advice.
Reference list

   http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=81565NED


43. Müller MJ, Bosy-Westphal A, Klaus S, et al. World Health Organization equations have shortcomings for predicting resting energy expenditure in persons from a modern, affluent


Appendix I: Statistical methods

Bias and RMSE
Bias is defined as the mean, systematic error between two variables: REE predicted with an equation and REE measured by IC. The bias is a prediction of accuracy in group mean data and reduces the validity of a measurement. Nevertheless group mean data mask larger individual errors.\(^{52}\)

The RMSE is defined as the root mean squared error which says something about the size and the deviation of the prediction errors on an individual level. It is calculated by the squared difference between REE measured by IC and REE predicted with an equation for each subject and summated. Finally, the square root of the average is taken and divided by the number of subjects. Scores in RMSE closer to zero are more propitious than relatively high scores.\(^{52,53,56}\)

Bland-Altman
The Bland-Altman plot was used to compare REE predicted with an equation and REE measured by IC. This plot is the difference of REE predicted and REE measured against their mean. Therefore this shows the measured error between the actual value. Bias is shown with limits of agreement. The limits of agreement are shown in The Bland-Altman plot. The Bland-Altman plot can be calculated by the mean difference minus 1.96 times the standard deviations and the mean difference summated 1.96 standard deviations of the mean difference. Within the Bland-Altman plot 95% of the differences lie between these limits.\(^{60,61}\)

Concordance correlation coefficient (CCC)
Correlation is about the statistical agreement of two variables. The correlation coefficient is a value that indicates the strength of the correlation between variables which is known as the Pearson correlation coefficient. The Pearson correlation coefficient measures the correlation between the predicted and the measured REE. The CCC takes also the deviation from the x=y line (Cb) into account. The CCC is the product of the Pearsons correlation coefficient and the Cb. When CCC=1, it means the equation predicts REE perfectly. When CCC=0, it means the equation is not accurate at all.\(^{62,63}\)
Appendix II: Syntax

DATASET ACTIVATE DataSet1.
*Aanmaak alle formules.

*Aanmaak Bernstein.
IF (SEX = 1) REE_Bernstein=(11.02 * WEIGHT_BP) + (10.23 * (HEIGHT *100)) - (5.8 * LFT) - 1032.
EXECUTE.
IF (SEX = 0) REE_Bernstein=(7.48 * WEIGHT_BP) + (0.42 * (HEIGHT * 100)) - (3 * LFT) + 844.
EXECUTE.

*Aanmaak FAO/WHO/UNU weight only 18-30y.
IF (SEX=1) REE_FAO_18_30y=(15.3 * WEIGHT_BP) + 679.
EXECUTE.
IF (SEX=0) REE_FAO_18_30y=(14.7 * WEIGHT_BP) + 496.
EXECUTE.

*Aanmaak FAO/WHO/UNU weight only 30-60y.
IF (SEX=1) REE_FAO_30_60y=(11.6 * WEIGHT_BP) + 879.
EXECUTE.
IF (SEX=0) REE_FAO_30_60y=(8.7 * WEIGHT_BP) + 829.
EXECUTE.

*Aanmaak FAO/WHO/UNU weight only >60y.
IF (SEX=1) REE_FAO_60yandolder=(13.5 * WEIGHT_BP) + 487.
EXECUTE.
IF (SEX=0) REE_FAO_60yandolder=(10.5 * WEIGHT_BP) + 596.
EXECUTE.

*Aanmaak FAO/WHO/UNU weight and height 18-30y.
IF (SEX=1) REE_FAO_18_30yWTHT=(15.4 * WEIGHT_BP) - (27 * HEIGHT) + 717.
EXECUTE.
IF (SEX=0) REE_FAO_18_30yWTHT=(13.3 * WEIGHT_BP) + (334 * HEIGHT) + 35.
EXECUTE.

*Aanmaak FAO/WHO/UNU weight and height 30-60y.
IF (SEX=1) REE_FAO_30_60yWTHT=(11.3 * WEIGHT_BP) - (16 * HEIGHT) + 901.
EXECUTE.
IF (SEX=0) REE_FAO_30_60yWTHT=(8.7 * WEIGHT_BP) - (25 * HEIGHT) + 865.
EXECUTE.

*Aanmaak FAO/WHO/UNU weight and height >60y.
IF (SEX=1) REE_FAO_60yWTHT=(8.8 * WEIGHT_BP) + (1128 * HEIGHT) - 1071.
EXECUTE.
IF (SEX=0) REE_FAO_60yWTHT=(9.2 * WEIGHT_BP) + (637 * HEIGHT) - 302.
EXECUTE.

*Aanmaak Harris & Benedict 1919.
IF (SEX=1) REE_HB_1919=66.4730 + (13.7516 * WEIGHT_BP) + (5.0033 * (HEIGHT * 100)) - (6.7550 * LFT).
EXECUTE.
IF (SEX=0) REE_HB_1919=665.0955 + (9.5634 * WEIGHT_BP) + (1.8496 * (HEIGHT * 100)) - (4.6756 * LFT).
EXECUTE.

*Aanmaak Harris & Benedict 1984.
IF (SEX=1) REE_HB_1984=88.362 + (4.799 * (HEIGHT * 100)) + (13.397 * WEIGHT_BP) - (5.677 * LFT).
EXECUTE.
IF (SEX=0) REE_HB_1984=447.593 + (3.098 * (HEIGHT * 100)) + (9.247 * WEIGHT_BP) - (4.330 * LFT).
EXECUTE.

*Aanmaak Henry. Weight only 30-60y.
IF (SEX = 1) REE_HENRY30T60=((0.0592 * WEIGHT_BP) + 2.48)* 1000/ 4.184.
EXECUTE.
IF (SEX = 0) REE_HENRY30T60=((0.0407 * WEIGHT_BP) + 2.9)*1000/ 4.184.
EXECUTE.

*Henry. Weight only >60y.
IF (SEX = 1) REE_HENRYolderthan60=((0.0563 * WEIGHT_BP) + 2.15)*1000/ 4.184.
EXECUTE.

IF (SEX = 0) REE_HENRYolderthan60=((0.0424 * WEIGHT_BP) + 2.38)*1000/ 4.184.
EXECUTE.

*Henry. Weight and Height 30-60y.
IF (SEX = 1) REE_HENRY_WTHT_30T60=((0.0476 * WEIGHT_BP) + (2.26 * HEIGHT) - 0.574)*1000/ 4.184.
EXECUTE.

IF (SEX = 0) REE_HENRY_WTHT_30T60=((0.0342 * WEIGHT_BP) + (2.10 * HEIGHT) - 0.0486)*1000/ 4.184.
EXECUTE.

*Henry. Weight and Height >60y.
IF (SEX = 1) REE_HENRY_WTHTolderthan60=((0.0478 * WEIGHT_BP) + (2.26 * HEIGHT) - 1.07)*1000/ 4.184.
EXECUTE.

IF (SEX = 0) REE_HENRY_WTHTolderthan60=((0.0356 * WEIGHT_BP) + (1.76 * HEIGHT) - 0.0448)*1000/ 4.184.
EXECUTE.

*Aanmaak Huang.
COMPUTE REE_HUANG=71.767 - (2.337 * LFT) + (257.293 * SEX) + (9.996 *WEIGHT_BP) + (4.132 * (HEIGHT * 100)).
EXECUTE.

* Aanmaak Korth.
COMPUTE REE_KORTH=((41.5 * WEIGHT_BP) + (35.0 * (HEIGHT * 100)) + (1107.4 * SEX) - (19.1 * LFT) - 1731.2) / 4.184.
EXECUTE.

*Aanmaak Lazzer 2007.
IF (SEX = 1) REE_LAZZER2007=((0.048 * WEIGHT_BP) + (4.655 *HEIGHT) - (0.020 * LFT) - 3.605)*1000/ 4.184.
EXECUTE.

IF (SEX = 0) REE_LAZZER2007=((0.042 * WEIGHT_BP) + (3.619 *HEIGHT) - 2.678)*1000/ 4.184.
EXECUTE.

*Aanmaak Lazzer 2010.
COMPUTE REE_LAZZER2010=((46 * WEIGHT_BP) - (14 * LFT) + (1.140 * SEX) + 3.252)/4.184.
EXECUTE.

*Aanmaak Livingston and Kohlstadt.
IF (SEX = 1) REE_LIVINGSTON=((53.284 * WEIGHT_BP) + (20.957 * (HEIGHT * 100)) - (23.859 * LFT) + 487)/4.184.
EXECUTE.

IF (SEX = 0) REE_LIVINGSTON=((46.322 * WEIGHT_BP) + (15.744 * (HEIGHT * 100)) - (16.66 * LFT) + 944)/4.184.
EXECUTE.

*Aanmaak de Lorenzo.
IF (SEX = 1) REE_LORENZO=(((53.284 * WEIGHT_BP) + (20.957 * (HEIGHT * 100)) - (23.859 * LFT) + 487)/4.184.
EXECUTE.

IF (SEX = 0) REE_LORENZO=((46.322 * WEIGHT_BP) + (15.744 * (HEIGHT * 100)) - (16.66 * LFT) + 944)/4.184.
EXECUTE.

*Aanmaak Lührmann.
COMPUTE REE_LUHRMAN=(3169 + (50.0  * WEIGHT_BP) - (15.3 * LFT) + (746 * SEX))/4.184.
EXECUTE.

*Aanmaak Mifflin 1990.
COMPUTE REE_MIFFLIN=(9.99 * WEIGHT_BP) + (6.25 * (HEIGHT * 100)) - (4.92 * LFT) + (166 * SEX) - 161.
EXECUTE.

*Aanmaak Müller.
COMPUTE REE_MÜLLER_ALLBMI=((0.047 * WEIGHT_BP) + (1.009 * SEX) - (0.01452 * LFT) + 3.21)*1000/ 4.184.
EXECUTE.

COMPUTE  REE_MÜLLER_BMI_25T30=((0.04507 * WEIGHT_BP) + (1.006 * SEX) - (0.01553 * LFT) + 3.407)*1000/ 4.184.
EXECUTE.
COMPUTE REE_MÜLLER_BMI_30andhigher=((0.05 * WEIGHT_BP) + (1.103 * SEX) - (0.01586 * LFT) + 2.924)*1000/ 4.184.
EXECUTE.

*Aanmaak Owen.
IF (SEX = 1) REE_OWEN=879 + (10.2 * WEIGHT_BP).
EXECUTE.
IF (SEX = 0) REE_OWEN=795 + (7.18 * WEIGHT_BP).
EXECUTE.

*Aanmaak Schofield.
IF (SEX = 1) REE_Schofield_18T30=((0.063 * WEIGHT_BP) + 2.896)*1000/ 4.184.
EXECUTE.
IF (SEX = 1) REE_Schofield_18T30_WTHT=((0.063 * WEIGHT_BP) - (0.042 * WEIGHT_BP) + 2.953)*1000/ 4.184.
EXECUTE.
IF (SEX = 0) REE_Schofield_18T30=((0.062 * WEIGHT_BP) + 2.036)*1000/ 4.184.
EXECUTE.
IF (SEX = 0) REE_Schofield_18T30_WTHT=((0.063 * WEIGHT_BP) + (0.042 * HEIGHT) + 2.953)*1000/ 4.184.
EXECUTE.
IF (SEX = 1) REE_Schofield_30T60=((0.048 * WEIGHT_BP) + 3.653)*1000/ 4.184.
EXECUTE.
IF (SEX = 1) REE_Schofield_30T60_WTHT=((0.048 * WEIGHT_BP) - (0.011 * HEIGHT) + 3.67)*1000/ 4.184.
EXECUTE.
IF (SEX = 0) REE_Schofield_30T60=((0.034 * WEIGHT_BP) + 3.538)*1000/ 4.184.
EXECUTE.
IF (SEX = 0) REE_Schofield_30T60_WTHT=((0.034 * WEIGHT_BP) + (0.006 * HEIGHT) + 3.53)*1000/ 4.184.
EXECUTE.
IF (SEX = 1) REE_Schofield_60andolder=((0.049 * WEIGHT_BP) + 2.459)*1000/ 4.184.
EXECUTE.
IF (SEX = 1) REE_Schofield_60andolder_WTHT=((0.049 * WEIGHT_BP) + (4.068 * HEIGHT) - 3.491)*1000/ 4.184.
EXECUTE.
IF (SEX = 0) REE_Schofield_60andolder=((0.038 * WEIGHT_BP) + 2.755)*1000/ 4.184.
EXECUTE.
IF (SEX = 0) REE_Schofield_60andolder_WTHT=((0.038 * WEIGHT_BP) + (1.917 * HEIGHT) + 0.074)*1000/ 4.184.
EXECUTE.

*Aanmaak Weijs.
IF (SEX = 1) REE_WEIJS=(16.790 * WEIGHT_BP) + (4.531 * (HEIGHT * 100)) + (0.169 * LFT) - 420.492.
EXECUTE.
IF (SEX = 0) REE_WEIJS=(12.753 * WEIGHT_BP) + (3.869 * (HEIGHT * 100)) - (1.489 * LFT) + 13.150.
EXECUTE.

*Aanmaak Bernstein FFM.
COMPUTE REE_Bernstein_FFM= (19.02 * LWkg_BP) + (3.72 * FATkg_BP) - (1.55 * LFT) + 236.7.
EXECUTE.

*Aanmaak Huang FFM.
COMPUTE REE_Huang_FFM= (14.118 * LWkg_BP) + (9.367 * FATkg_BP) - (1.515 * LFT) + (220.863 * SEX) + 521.995.
EXECUTE.

*Aanmaak Johnstone FFM.
COMPUTE REE_Johnstone_FFM= (1613 + (31.6 * FATkg_BP) + (90.2 * LWkg_BP) - (12.2 * LFT))/4.184.
EXECUTE.

*Aanmaak Korth FFM.
COMPUTE REE_Korth_FFM=((108.1 * LWkg_BP) + 1231)/4.184.
EXECUTE.

*Aanmaak Lazzer 2007 FFM.
IF (SEX = 1) REE_Lazzer_FFM_2007=((0.081 * LWkg_BP) + (0.049 * FATkg_BP) - (0.019 * LFT) - 2.194)*1000/4.184.
EXECUTE.
IF (SEX = 0) REE_Lazzer_FFM_2007=((0.067 * LWkg_BP) + (0.046 * FATkg_BP) + 1.568)*1000/4.184.
EXECUTE.

*Aanmaak Lazzer 2010 FFM.
COMPUTE REE_Lazzer_FFM_2010=((82 * LWkg_BP) - (10 * LFT) - (44 * SEX) + 3.517)/4.184 .
EXECUTE.

*Aanmaak Mifflin FFM.
COMPUTE Mifflin_FFM=(19.7 * LWkg_BP) + 413.
EXECUTE.

*Aanmaak Müller FFM.
COMPUTE REE_MÜLLER_FFM=((0.05192*LWkg_BP)+ (0.04036 * FATkg_BP)+(0.869*SEX)- (0.01181 * LFT)+
 2.992)*1000/4.184.
EXECUTE.

*Aanmaak Müller FFM BMI <30.
COMPUTE REE_MÜLLER_BMI25T30_FFM=((0.03776*LWkg_BP)+ (0.03013 * FATkg_BP)+(0.93*SEX)- (0.01196 *
  LFT)+ 3.928)*1000/4.184.
EXECUTE.

*Aanmaak Müller FFM BMI>30.
COMPUTE REE_MÜLLER_BMI30andhigher_FFM=((0.05685*LWkg_BP)+ (0.04022 * FATkg_BP)+(0.808*SEX)- (0.01402 *
  LFT)+ 2.818)*1000/4.184.
EXECUTE.

*Aanmaak Owen FFM.
IF  (SEX = 1) REE_OWEN_FFM=290+(22.3*LWkg_BP).
EXECUTE.
IF  (SEX = 0) REE_OWEN_FFM=334+(19.7*LWkg_BP).
EXECUTE.

*Aanmaak Formule Klaver-Rootjes.
COMPUTE REE_AR2=257.990 + (208.508 * SEX) - (5.398 * LFT) + (11.017 * WEIGHT_BP) + (436.796 *
  HEIGHT).
EXECUTE.

*Aanmaak eigen formule Klaver-Rootjes FFM.
COMPUTE REE_annaroos_FFM=573.969 + (38.139 * SEX) - (4.149 * LFT) + (7.418 * FATkg_BP) + (21.434 * LWkg_BP).
EXECUTE.

*Aanmaak Klaver-Rootjes Gender.
IF (SEX = 1) REE_Klaver_Rootjes=1434.934 - (6.459 * LFT ) + (11.076 * WEIGHT_BP) - (76.819 * HEIGHT ).
EXECUTE.
IF (SEX = 0) REE_Klaver_Rootjes=-307.994 - (4.227 * LFT) + (10.673 * WEIGHT_BP) + (753.495 * HEIGHT).
EXECUTE.

*Aanmaak Klaver-Rootjes Gender FFM.
IF (SEX = 1) REE_Klaver_Rootjes_FFM=972.405 - (7.512 * LFT) + (7.184 * FATkg_BP) + (19.220 * LWkg_BP).
EXECUTE.
IF (SEX = 0) REE_Klaver_Rootjes_FFM=318.565 - (1.571 * LFT) + (7.047 * FATkg_BP) + (23.837 * LWkg_BP).
EXECUTE.

REGRESSION
/MISSING LISTWISE
/STATISTICS COEFF OUTS R ANOVA
/CRITERIA=PIN(.05) POUT(.10)
/NOORIGIN
/DEPENDENT REE_kcal_IC
/METHOD=ENTER SEX LFT WEIGHT_BP HEIGHT.

REGRESSION
/MISSING LISTWISE
/STATISTICS COEFF OUTS R ANOVA

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/CRITERIA=PIN(.05) POUT(.10)
/NOORIGIN
/DEPENDENT REE_kcal_IC
/METHOD=ENTER SEX LFT FATkg_BP LWkg_BP.

REGRESSION
/MISSING LISTWISE
/STATISTICS COEFF OUTS R ANOVA
/CRITERIA=PIN(.05) POUT(.10)
/NOORIGIN
/DEPENDENT REE_kcal_IC
/METHOD=ENTER LFT FATkg_BP LWkg_BP.

REGRESSION
/MISSING LISTWISE
/STATISTICS COEFF OUTS R ANOVA
/CRITERIA=PIN(.05) POUT(.10)
/NOORIGIN
/DEPENDENT REE_kcal_IC
/METHOD=ENTER LFT WEIGHT_BP HEIGHT.

DATASET ACTIVATE Dataset3.

DESCRIPTIVES VARIABLES=LFT WEIGHT_BP HEIGHT BMI FATkg_BP FATP_BP LWkg_BP REE_kcal_IC
/STATISTICS=MEAN STDDEV MIN MAX.

USE ALL.
COMPUTE filter_$=(SEX=1).
VARIABLE LABELS filter_$ 'SEX=1 (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.

DESCRIPTIVES VARIABLES=LFT WEIGHT_BP HEIGHT BMI FATkg_BP FATP_BP LWkg_BP REE_kcal_IC
/STATISTICS=MEAN STDDEV MIN MAX.

USE ALL.
COMPUTE filter_$=(SEX=0).
VARIABLE LABELS filter_$ 'SEX=0 (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.

T-TEST
/TESTVAL=0
/MISSING=ANALYSIS
/VARIABLES=LFT GEB_DATUM WEIGHT_BP FATP_BP FATkg_BP LWkg_BP WEIGHT_BP HEIGHT BMI REE_kcal_IC
/CRITERIA=CI(.95).

DESCRIPTIVES VARIABLES=SEX LFT WEIGHT_BP FATP_BP FATkg_BP LWkg_BP WEIGHT_BP HEIGHT BMI REE_kcal_IC FFMPct
/STATISTICS=MEAN STDDEV MIN MAX.

USE ALL.
COMPUTE filter_$=(SEX = 1).
VARIABLE LABEL filter_$ 'SEX = 1 (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMAT filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.

T-TEST GROUPS=SEX(0 1)
/MISSING=ANALYSIS
/VARIABLES=LFT WEIGHT_BP FATP_BP FATkg_BP LWkg_BP HEIGHT BMI REE_kcal_IC FFMpct
/CRITERIA=CI(.95).

DATASET ACTIVATE DataSet2.

DESCRIPTIVES VARIABLES=REE_Bernstein REE_FAO_18_30y REE_FAO_30_60y REE_FAO_60yandolder
REE_FAO_18_30yWTHT REE_FAO_30_60yWTHT REE_FAO_60yWTHT REE_HB_1919 REE_HB_1984 REE_HENRY30T60
REE_HENRYolderthan60 REE_HENRY_WTHT_30T60 REE_HENRY_WTHTolderthan60 REE_HUANG REE_KORTH
REE_LAZZER2007 REE_LAZZER2010 REE_LIVINGSTON REE_LORENZO REE_LUHRMAN REE_MIFFLIN
REE_MÜLLER_ALLBMI REE_MÜLLER_BMI_25T30 REE_MÜLLER_BMI_30andhigher REE_OWEN REE_Schofield_18T30
REE_Schofield_18T30_WTHT REE_Schofield_30T60 REE_Schofield_30T60_WTHT REE_Schofield_60andolder
REE_Schofield_60andolder_WTHT
/STATISTICS=MEAN STDDEV MIN MAX.

DESCRIPTIVES VARIABLES=REE_kcal_IC REE_Bernstein_FFM REE_Huang_FFM REE_Johnstone_FFM REE_Korth_FFM
REE_Lazzer_FFM_2007 REE_Lazzer_FFM_2010 Mifflin_FFM REE_MÜLLER_FFM REE_MÜLLER_BMI25T30_FFM
REE_MÜLLER_BMI30andhigher_FFM REE_OWEN_FFM REE_AR_FMM REE_Klaver_Rootjes_FFM REE_Klaver_Rootjes
/STATISTICS=MEAN STDDEV MIN MAX.

DATASET ACTIVATE DataSet2.

DESCRIPTIVES VARIABLES=Bias_Bernstein Bias_FAO_18_30y Bias_FAO_30_60y Bias_FAO_60yandolder
Bias_FAO_18_30yWTHT Bias_FAO_30_60yWTHT Bias_FAO_60yWTHT Bias_HB_1919 Bias_HB_1984 Bias_HENRY30T60
Bias_HENRYolderthan60 Bias_HENRY_WTHT_30T60 Bias_HENRY_WTHTolderthan60 Bias_HUANG Bias_KORTH
Bias_LAZZER2007 Bias_LAZZER2010 Bias_LIVINGSTON Bias_LORENZO Bias_LUHRMAN Bias_MIFFLIN
Bias_MÜLLER_ALLBMI Bias_MÜLLER_BMI_25T30 Bias_MÜLLER_BMI_30andhigher Bias_OWEN Bias_Schofield_18T30
Bias_Schofield_18T30_WTHT Bias_Schofield_30T60 Bias_Schofield_30T60_WTHT Bias_Schofield_60andolder
Bias_Schofield_60andolder_WTHT
/STATISTICS=MEAN STDDEV MIN MAX.

DESCRIPTIVES VARIABLES=Bias_WEIJS Bias_Bernstein_FFM Bias_Huang_FFM Bias_Johnstone_FFM
Bias_Korth_FFM Bias_Lazzer_FFM_2007 Bias_Lazzer_FFM_2010 BiasMifflin_FFM Bias_MÜLLER_FFM
Bias_MÜLLER_BMI25T30_FFM Bias_MÜLLER_BMI30andhigher_FFM Bias_OWEN_FFM Bias_AR2 Bias_AR_FMM
Bias_Klaver_Rootjes Bias_Klaver_Rootjes_FFM
/STATISTICS=MEAN STDDEV MIN MAX.

DESCRIPTIVES VARIABLES=UO_Bernstein UO_FAO_18_30y UO_FAO_30_60y UO_FAO_60yandolder
UO_FAO_18_30yWTHT UO_FAO_30_60yWTHT UO_FAO_60yWTHT UO_HB_1919 UO_HB_1984 UO_HENRY30T60
UO_HENRYolderthan60 UO_HENRY_WTHT_30T60 UO_HENRY_WTHTolderthan60 UO_HUANG UO_KORTH
UO_LAZZER2007 UO_LAZZER2010 UO_LIVINGSTON UO_LORENZO UO_LUHRMAN UO_MIFFLIN UO_MÜLLER_ALLBMI
UO_MÜLLER_BMI_25T30 UO_MÜLLER_BMI_30andhigher UO_OWEN UO_Schofield_18T30 UO_Schofield_18T30_WTHT UO_Schofield_30T60
UO_Schofield_30T60_WTHT UO_Schofield_60andolder UO_Schofield_60andolder_WTHT UO_WEIJS UO_annaroos
UO_Klaver_Rootjes
/STATISTICS=MEAN STDDEV MIN MAX.

DESCRIPTIVES VARIABLES=UO_Klaver_Rootjes UO_AR2 UO_Bernstein_FFM UO_Huang_FFM UO_Johnstone_FFM
UO_Korth_FFM UO_Lazzer_FFM_2007 UO_Lazzer_FFM_2010 UO_Mifflin_FFM UO_MÜLLER_FFM
UO_MÜLLER_BMI25T30_FFM UO_MÜLLER_BMI30andhigher_FFM UO_OWEN_FFM UO_annaroos UO_AR_FMM
UO_Klaver_Rootjes_FFM
/STATISTICS=MEAN STDDEV MIN MAX.