



universität
wien

MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

Comparison of different energy equations with the actual
energy intake

verfasst von / submitted by

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angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of
Master of Science (MSc)

Wien, 2015 / Vienna 2015

Studienkennzahl lt. Studienblatt /
degree programme code as it appears on
the student record sheet:

A 066838

Studienrichtung lt. Studienblatt /
degree programme as it appears on
the student record sheet:

Masterstudium Ernährungswissenschaften

Betreut von / Supervisor:

Univ.-Prof- Mag. Dr. Karl-Heinz Wagner

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Abbreviations

<i>AMI</i>	Area Mass Index
<i>BIA</i>	Bioelectrical Impedance Analysis
<i>BMI</i>	Body Mass Index
<i>BMR</i>	Basal Metabolic Rate
<i>EI</i>	Energy Intake
<i>EPIC</i>	European Prospective Investigation into Cancer and Nutrition
<i>FAO</i>	Food and Agriculture Organization of the United Nations
<i>IBW</i>	Ideal Body Weight
<i>MET</i>	Metabolic Equivalent of Task
<i>PAL</i>	Physical Activity Level
<i>REE</i>	Resting Energy Expenditure
<i>RMR</i>	Resting Metabolic Rate
<i>TEE</i>	Total Energy Expenditure
<i>UNU</i>	United Nations University
<i>WHO</i>	World Health Organization
<i>WHR</i>	Waist to Hip Ratio

1) Introduction

Worldwide the weight of the population is increasing, whereas the physical activity behaviour is decreasing. That strengthens the need for weight reduction programs. However, interventions and weight reduction programs do very often not have the effect participants are looking for. Frustration often leads back to unhealthy eating habits and a gain of the previously lost weight (Eurobarometer 2006, Finucane, Stevens et al. 2011). One reason why the weight reduction programs often fail, could be the overestimation of the recommended energy intake by the predictive energy equations. Therefore overweight and obese people are maybe eating less than recommended, but still too much to lose weight (Siervo, Boschi et al. 2003, Anderson, Sylvia et al. 2014).

The energy equations mostly used in Europe are the two equations developed by Schofield for the WHO, FAO and UNU in 1985 (Schofield 1984, Joint and Organization 1985). For years now studies criticize the overestimation of the energy expenditure due to bias during the investigation period (Frankenfield 2013). But still it is highly recommended by the WHO and FAO and commonly used in weight reduction programs. In the U.S. however the energy equation developed by Harris and Benedict is the most frequently used. The equation is even older than the one from Schofield and was established in 1919 (Harris and Benedict 1919). In the last hundred years a lot changed, not only in terms of individual eating habits, but also in terms of the study equipment. With the modern medical equipment today, a lot of studies proved that the Harris-Benedict equation tends to overestimate the energy expenditure of men and women (Frankenfield, Muth et al. 1998).

A lot of other different energy equations have been developed meanwhile, but none of them could established the same popularity as the ones by Harris and Benedict and Schofield. Most of the studies were done by measuring the basal metabolic rate (BMR) or the resting metabolic rate (RMR) by indirect calorimetry, some included a meta-analysis and the most recent study measured the body surface (Frankenfield, Roth-Yousey et al. 2005, Schlich, Schumm et al. 2010, Frankenfield 2013). A comparison of all the different studies can be found in the following literature research of the thesis.

The aim of the presented study was to compare the eight different predictive energy equations among each other and with the actual energy intake, measured by 102 female subjects. Over

the investigation period of one month a dietary record with all consumed foods, a record with physical activities and a record with the morning weight was completed during the first and the last week of participation. For the analysis the equations of Harris-Benedict, Schofield, Mifflin-St. Jeor, Owen, Livingston, Müller, Oxford and the Area Mass Index (AMI) were included.

2) Literature review

For a deeper insight into the topic and to get an overview of the energy equations included in the present study, a literature research was conducted, starting with the first popular energy equation by Harris and Benedict in 1919 and finishing with the latest innovative one, the area mass index in 2010.

Harris-Benedict

One of the oldest energy equations still used today, was developed by James Harris and Francis Benedict and first mentioned in their book “A biometric study of basal metabolism in man” in 1919. The equation is as follows (Harris and Benedict 1919):

For men: $\text{BMR (kcal)} = 66.5 + (13.75 \times \text{weight in kg}) + (5.003 \times \text{height in cm}) - (6.755 \times \text{age in years})$

For women: $\text{BMR (kcal)} = 655 + (9.563 \times \text{weight in kg}) + (1.850 \times \text{height in cm}) - (4.676 \times \text{age in years})$

Over a period of eight years, from 1909 till 1917, the basal metabolic rate (BMR) of 136 men and 103 women was examined. Due to the reason that the lowest metabolic rate occurs in the early morning hours during deep sleep, the subjects had to stay under strict experimental conditions for the whole time of participation. The basal metabolic rate was measured by indirect calorimetry in the morning for 5 to 15 minutes during sleep and after an overnight fast (Harris and Benedict 1919, Frankenfield, Muth et al. 1998).

Originally Harris and Benedict planned to develop an equation in order to diagnose hypo- and hyperthyroidism and not to estimate the energy expenditure. It was the first time that biometric principles were used for analysis, making it a significant progress compared to previous work. This innovative equation gained huge attention and even today it is still used very frequently, especially in the United States (Harris and Benedict 1919, Frankenfield, Muth et al. 1998).

All other studies described here developed their energy equations by measuring the Resting Metabolic Rate (RMR) by indirect calorimetry in the morning after a 12-hour overnight fast, meaning the study by Harris and Benedict is so far the only one, which measured the BMR and not the RMR (Harris and Benedict 1919, Henry 2005). While measuring the BMR it is necessary

that the sympathetic nervous system is not stimulated, which is not required during the measurements of the RMR (Frankenfield, Muth et al. 1998). However, BMR is often used as a synonym for the RMR, also in some of studies mentioned later (Schofield 1984, Henry 2005).

In 1919, Harris and Benedict's study was an innovation of metabolic principles, but it's been almost one hundred years since this medical investigation has been completed (Frankenfield, Muth et al. 1998). Already in 1985 Daly et al. published an article stating that the Harris-Benedict equation tends to overestimate the basal energy requirements by 10 to 15%. For specific groups of the population, like overweight and obese subjects the overestimation even increased to 30% (Daly, Heymsfield et al. 1985).

In the last decades a lot of research has been conducted in order to find solutions for the criticism of energy equations today. Some articles pointed out that the lifestyle changes were too broad during the last century, making the equation unsuitable for the modern society today. Furthermore the estimated energy expenditure increases with weight, leading to a high energy recommendation for overweight and obese subjects where it rather should recommend an energy intake similar to subjects with normal weight (Frankenfield, Roth-Yousey et al. 2005, Anderson, Sylvia et al. 2014).

Observing the study sample recruited by Harris and Benedict in 1919, it indeed does not reflect the present population. The age of the study sample ranged between 15 and 74 years, with an average of 27 ± 9 years for males and 31 ± 14 years for females (Harris and Benedict 1919). This does not reflect the average age of the European population nowadays, which raised to 42 years during the last years (Yearbook 2012). Furthermore the recruited subjects were very lean and physical active. The women had a mean weight of 56.5 ± 11.5 kg and a mean BMI of 21.4 ± 2.8 kg/m². The men had a mean weight of 64.1 ± 10.3 kg and a mean BMI of 21.5 ± 4.1 kg/m², which is completely different to the mean weight of today's population (Harris and Benedict 1919). The European Commission stated in 2015 that the mean weight for adults in Europe is 72.2 kg. So today the mean population is at least 10 kg heavier and 10 years older than one hundred years ago (Eurobarometer 2006, Yearbook 2012).

Not only the mean age and the average body weight of today's population changed, but also the instruments used for medical examinations have been improved. Due to modernisation many instruments were upgraded and innovative methods have been invented in order to receive more information about human metabolism. Additionally already established methods were further refined (Frankenfield, Muth et al. 1998, Elizabeth Weekes 2007).

However, it must be acknowledged that Harris and Benedict were clearly ahead of their time with their established equation (Frankenfield, Muth et al. 1998, Henry 2005). When using this equations today one needs to keep in mind that a lot has changed in the last century such as body composition, food habits , food intake, body weight and frequency of physical activity (Finucane, Stevens et al. 2011). So it cannot be guaranteed, that the equation developed by Harris and Benedict in 1919 is still as accurate in our modern society.

Schofield

At the beginning of the 1980s the FAO, WHO and UNU assigned Schofield to develop a new predictive energy equation for their recommendations (Joint and Organization 1985). The new equations were discussed during the 1985 WHO, FAO and UNU consultation in Geneva, Switzerland and published afterwards in the report “Energy and Protein Requirements” of the WHO, making it available for the public (Joint and Organization 1985).

For the elaboration Schofield performed a meta-analysis of 114 published studies, over a time period of 66 years (from 1914 until 1980). This means that also the data points of the study of Harris and Benedict are included in this analysis. Summing up all data from the different studies, Schofield collected a total of 7173 data points of European and North American heritage (Schofield 1984).

After the evaluation, Schofield established two different equations. The first one includes just the information on weight, while the second one includes weight and height. After evaluating the two equations, the results showed that both were accurate. Therefore the WHO published the first as well as the second energy equation in their report. Today both equations are used and recommended (Schofield 1984, Joint and Organization 1985).

The definition of the first equation, including only weight is (Schofield 1984):

For men: aged 18 – 30 years: $RMR (kcal) = (15.3 \times \text{weight in kg}) + 679$

aged 31 – 60 years: $RMR (kcal) = (11.6 \times \text{weight in kg}) + 879$

aged >60 years: $RMR (kcal) = (13.5 \times \text{weight in kg}) + 487$

For women: aged 18 – 30 years: $RMR (kcal) = (14.7 \times \text{weight in kg}) + 496$

aged 31 – 60 years: $RMR (kcal) = (8.7 \times \text{weight in kg}) + 829$

aged >60 years: $RMR (kcal) = (10.5 \times \text{weight in kg}) + 596$

For the second equation, including weight and height the definition is (Schofield 1984):

For men: aged 18 – 30 years: $RMR\ (kcal) = (15.4 \times \text{weight in kg}) - (27 \times \text{height in m}) + 717$
aged 31 – 60 years: $RMR\ (kcal) = (11.3 \times \text{weight in kg}) + (16 \times \text{height in m}) + 901$
aged >60 years: $RMR\ (kcal) = (8.8 \times \text{weight in kg}) + (1128 \times \text{height in m}) - 1071$
For women: aged 18 – 30 years: $RMR\ (kcal) = (13.3 \times \text{weight in kg}) + (334 \times \text{height in m}) + 35$
aged 31 – 60 years: $RMR\ (kcal) = (8.7 \times \text{weight in kg}) - (25 \times \text{height in m}) + 865$
aged >60 years: $RMR\ (kcal) = (9.2 \times \text{weight in kg}) + (637 \times \text{height in m}) - 302$

The same year first criticism was expressed due to an overestimation of the energy expenditure when using the equation (Daly, Heymsfield et al. 1985). Schofield himself stated that the database contains a disproportionate high number of Italian males. He re-evaluated the equations but continued with the first developed ones (Schofield 1984). Until now these energy equations are recommended by the WHO and FAO and most frequently used in Europe.

A lot of studies criticised the high number of Italian subjects in the study. Of the total 7173 evaluated data points, 3388 were from Italian descent, making it 47% of the total study population. Furthermore most of them were young military and police recruits, which had a higher BMR per kg body weight than any other group in the study sample. While their higher BMR was a result of the greater muscle mass, it also leads to an overestimation of the BMR for subjects with a higher weight, despite higher muscle or fat mass (Horgan and Stubbs 2003, Frankenfield, Roth-Yousey et al. 2005, Henry 2005, Weijs and Vansant 2010, Frankenfield 2013). Due to the high body weight the estimated energy expenditure increases, but does not take into account the higher body fat, which doesn't contribute to the energy metabolism (Horgan and Stubbs 2003, Hasson, Howe et al. 2011).

Another critical point nowadays, is the lack of diversity. Energy equations are recommended to be used globally, but the only subjects included in the meta-analysis were Caucasians from Europe and North America. So it is not surprising that several studies reported an overestimation of the energy expenditure in the Asian population, as well as in individuals living in tropical regions (Case, Brahler et al. 1997, Piers, Diffey et al. 1997, Henry 2005, Hasson, Howe et al. 2011).

Despite the criticism, the equations developed by Schofield played a significant role in re-establishing the use and the importance of the BMR as a prediction for the human energy requirement (Joint and Organization 1985, Henry 2005). Two recent studies showed that the Schofield equation is still most adequate in calculating the energy expenditure for women, although just for overweight and obese women from Spain and Brazil (Hasson, Howe et al. 2011, Rosado, de Brito et al. 2014).

Owen

In 1985 Oliver Owen and his research team developed a new energy equation based on a study sample from the General Clinical Research Centre at the Temple University Hospital in Philadelphia. One year later they published two papers, one containing background information for women and one for men. The definitions for the two energy equations are (Owen, Kavle et al. 1986, Owen, Holup et al. 1987):

For men: $\text{RMR (kcal)} = 879 + (10.2 \times \text{weight in kg})$
For women: $\text{RMR (kcal)} = 795 + (7.18 \times \text{weight in kg})$

Owen et al. conducted their study with a total of 104 subjects, of whom 60 were men and 44 were women. They measured their RMR by indirect calorimetry in the morning, after an overnight fast and before breakfast (Owen, Kavle et al. 1986, Owen, Holup et al. 1987). Since the study presented in this thesis includes only women, the discussion of the data of Owen et al. also focuses on women.

Of the 44 women that were recruited, one was underweight, 23 were normal weight, four were overweight, ten obese and six extremely obese. All subjects had to maintain a balanced diet and a stable weight for at least one month before study entry. Furthermore no indication of a disease, normal blood sugar and a normal thyroid function were required (Owen, Kavle et al. 1986).

Owen et al. focused on a high heterogeneity for both study groups, whereby including people from white, black and Asian heritage, as well as extremely obese individuals and well trained athletes. Particular the female group had a high percentage of athletes, with eight out of 44 subjects. Therefore the athletes were excluded from the equation for the general population,

establishing two separate equations for women (for athletes and non-athletes). While the non-athletes were defined as the average physical active woman the athletes had to be competitors in physical events, with even two Olympic contestants. The two different equations are as follows (Owen, Kavle et al. 1986):

For non-athletes: RMR (kcal) = 795 + (7.18 x weight in kg); as mentioned above

For athletes: RMR (kcal) = 50.4 + (21.1 x weight in kg)

The recruited women reflect the female population in Europe of today much better, with a mean age of 35 ± 12 years (and a range from 18 till 65 years) and a mean weight of 74.9 ± 24.6 kg (and a range from 43 till 143 kg). For Europeans the average age at present is now 40 years and the mean body weight is 72.2 kg, which is reflected clearly by the study population of Owen et al. (Owen, Kavle et al. 1986, Eurobarometer 2006, Yearbook 2012).

Recent publications showed that the equation established by Owen et al. is one of the most reliable equations when calculating energy expenditure (Siervo, Boschi et al. 2003, Weijs and Vansant 2010). Although, being published in the same year as the Schofield equation it never received the same scientific attention.

Mifflin-St. Jeor

In 1990, after a 5 year investigation period Mark Mifflin, Sachiko St. Jeor and their study group published their energy equation in an article entitled "A new predictive equation for resting energy expenditure in healthy individuals". The two equations are (Mifflin, St Jeor et al. 1990):

For men: RMR (kcal) = (10 x weight in kg) + (6.25 x height in cm) – (5 x age in years) + 5

For women: RMR (kcal) = (10 x weight in kg) + (6.25 x height in cm) – (5 x age in years) – 161

Mifflin, St. Jeor et al. recruited a total of 247 women and 251 men, and assessed the resting energy expenditure (REE) by indirect calorimetry in the morning, after an overnight fasting period. Whereas earlier equations like Harris-Benedict and Schofield were based on a lean study population, Mifflin, St. Jeor et al. recruited a higher percentage of overweight and obese subjects. They divided the study population in obese and lean subjects and defined obese as a body weight of more than 120% of the ideal body weight (IBW). That lead to a total of 112 obese

women and 122 obese men, what is equal to total of 49% of obese subjects in the whole study population (Mifflin, St Jeor et al. 1990). Recent studies acknowledged their effort by stating, that the Mifflin-St. Jeor equation is the most appropriate not only for determining the metabolic rate at normal weight but also in obese individuals (Frankenfield, Rowe et al. 2003, Weijs and Vansant 2010, Frankenfield 2013).

A limitation Mifflin, St. Jeor et al. mentioned critically was the inclusion of the Caucasian race only. Therefore it was suggested that the estimation of the energy expenditure should be done with respect to other races, where an even higher overestimation can be found (Mifflin, St Jeor et al. 1990, Hasson, Howe et al. 2011, Nün Sava-Siva, Eduardo et al. 2012).

Müller

Müller et al. published the largest German study on predictive energy equations in 2004. The investigation period took 18 years and resulted in the following equations (Müller, Bosy-Westphal et al. 2004):

For men: RMR (kcal) = (11 x weight in kg) – (3.5 x age in years) + 764 + 240

For women: RMR (kcal) = (11 x weight in kg) – 3.5 x age in years) + 764

From the studies on predictive energy equations described above this is the first study which also considered children and adolescents. In total 2528 individuals (1027 males and 1501 females) were recruited in seven different research centres in Germany. In all subjects weight and height was measured. The whole study sample was divided in two subgroups, where the body composition was either assessed by bioelectrical impedance analysis (BIA) or skinfold-thickness measurements. The REE was evaluated by indirect calorimetry in the morning after an overnight fasting period in all subjects (Müller, Bosy-Westphal et al. 2004).

Randomly the whole population was separated into two subgroups. Based on the first group the equation was generated and again validated with the second group. In the results Müller et al. stated, that the equation has a more adequate estimation of the actual energy expenditure of a modern German population than the ones from Harris-Benedict or Schofield (Müller, Bosy-Westphal et al. 2004). Recent studies showed, that the energy equation by Müller et al. predicts

in fact a more accurate energy expenditure than Harris-Benedict and Schofield, but not as accurate as Owen and Mifflin-St. Jeor (Weijs and Vansant 2010, Frankenfield 2013).

Livingston

In 2005 Livingston and Kohlstadt published their innovative energy equation for calculating the energy expenditure of individuals. The equation is as follows (Livingston and Kohlstadt 2005):

For men: $\text{RMR (kcal)} = (293 \times \text{weight}^{0.433} \text{ in kg}) - (5.92 \times \text{age in years})$

For women: $\text{RMR (kcal)} = (248 \times \text{weight}^{0.43356} \text{ in kg}) - (5.09 \times \text{age in years})$

Livingston and Kohlstadt started their research on a new energy equation to determine the minimal energy requirement for patients receiving nutritional therapy and patients taking part in weight loss programmes. Therefore they collected data from the studies of Harris and Benedict (136 males and 103 females), Owen (60 males and 44 females) and recruited 327 new subjects from a university-based weight management program. For their own database they chose mostly obese patients, which were starting a very low calorie diet and measured their RMR by indirect calorimetry, in the morning after an overnight fasting period (Livingston and Kohlstadt 2005).

From the total number of 670 data points they created an energy equation including only weight. After validation they realised that only the body weight was not accurate enough to predict the energy expenditure. Therefore they added age and sex to the final energy equation (Livingston and Kohlstadt 2005).

Not many studies included the Livingston equation to their analysis. However the few results have been very positive, stating that its accuracy is similar to Mifflin-St. Jeor and Owen (Weijs and Vansant 2010, Frankenfield 2013).

Oxford

Since the above mentioned energy equations calculated appropriate predictions for populations, but not individuals, Henry developed a new equation and published it in 2005. Even though it was Henry who established the equation, the studies have been performed at Oxford University, leading to the name Oxford equation. The equations are (Henry 2005):

For men: $RMR\ (kcal) = (13.75 \times \text{weight in kg}) + (5 \times \text{height in m}) - (6.8 \times \text{age in years}) + 66$

For women: $RMR\ (kcal) = (9.6 \times \text{weight in kg}) + (1.8 \times \text{height in m}) - (4.7 \times \text{age in years}) + 655$

For the meta-analysis Henry collected all data points from the studies of Harris and Benedict and Schofield without the Italian subjects. He further added more data points of studies including subjects of higher age and different ethnic backgrounds, particularly the tropical region, since there had been a lack of racial diversity in the development of former energy equations (Owen, Holup et al. 1987, Mifflin, St Jeor et al. 1990, Vander Weg, Watson et al. 2004, Henry 2005, Hasson, Howe et al. 2011). Henry excluded all studies without individual data points and just the means, ending up with a total of 166 separate investigations. This is a total of 10552 subjects, 5794 men and 4702 women, making it the largest study sample with the highest ethnic diversity so far (Henry 2005).

Since this energy equation is still new, not many evaluations have been performed so far. Most of them however, stated that the Oxford equation is more accurate than Schofield but not as accurate as Mifflin-St. Jeor or Livingston (Elizabeth Weekes 2007, Frankenfield 2013).

Area Mass Index (AMI)

In 2009 another German study was conducted by Elmar Schlich and his research team to develop a new energy equation. In contrast to the above described equations it had a totally new and innovative concept. It is based on the hypothesis that people with a greater body surface tend to exchange more heat with the environment and therefore have a lower body weight (Schlich, Schumm et al. 2010, Schlich 2014).

A major element of the energy balance is the exchange of heat between the human body and the environment. The heat emission accounts for a total of 60 to 70% of the energy balance. Crucial for the amount of heat emanating into the environment is the specific body surface. A greater body surface, which can be found by tall and lean individuals, leads to a greater heat exchange and vice versa. While smaller and more compact individuals have not only a minor body surface, they also have a slightly higher amount of body fat. This leads to an isolating effect of the body and therefore decreases the amount of heat radiating into the environment. The opposite applies for lean individuals. Furthermore these effects act self-reinforcing, making it

harder for overweight people to lose and for lean people to gain weight (Schlich, Schumm et al. 2010, Schlich 2014).

Based on this theory, the hypothesis was tested, whether a greater body surface and therefore a greater heat exchange is linked to a more efficient metabolism in the body, leading to a lower weight while maintaining a steady daily energy intake (Schlich, Schumm et al. 2010, Schlich 2014).

Therefore 188 subjects were recruited, of whom were 132 women, aged 20 till 84 years, 49 men, aged 21 till 68 years, and seven children. The body surface of all subjects was measured via 3D-Body-Scan in four different positions (sitting and standing). All data was then divided into three groups of males, females and children and therefrom the average heat emission for each group was calculated. From the average heat exchange of body and environment it was estimated how much energy as 'calories' is indispensable for the human body. These calculations lead to establishing the energy equation of the 'area mass index', which is defined as the ratio of the body mass in kilograms to the body surface (Schlich, Schumm et al. 2010, Schlich 2014).

The AMI-equation which calculates the energy expenditure has not been published so far. Therefore no studies compared the AMI to other energy equations, which was the aim of this master thesis.

3) Methods

This study was conducted at the Department of Nutritional Sciences at the University in Vienna and aimed at evaluating the above mentioned equation of the Area Mass Index. Therefore 102 subjects were recruited and their height, weight and the circumferences of hip, waist and neck were measured. The subjects had to complete two 7 day dietary records of their food intake, physical activity behaviour and morning weight over the period of one month. The average energy intake was evaluated with the nutritional software nut.s and the physical activity was converted into MET/h. More detailed information can be found in the Methods section of the following manuscript.

The statistical analysis was performed with the program SPSS for Windows, Version 21.0. In a first analysis the actual energy intake was compared with the energy intake recommended by the AMI. Furthermore it was assessed if the weight of the subjects had changed during the study

and whether this was influenced by energy intake and/or physical activity. In a second analysis the recommendation of the AMI was compared to the ones by Harris-Benedict and Schofield.

Since the AMI is novel and hardly investigated, it was compared with the seven different energy equations mentioned earlier. The following manuscript includes this comparison and represents the main part of this thesis.

4) Manuscript: “Comparison of different energy equations with the actual energy intake”

Background

Over the last decade the food habits changed globally. Many people maintain an unhealthy lifestyle with an excessive energy intake and a physical activity behaviour that is too low, leading to a constant increase of weight. The growing number of overweight and obese subjects seeks help in weight reduction programs, but quite often without success. Frustration is followed by the same eating behaviours as before, accompanied by the gain of the previous lost weight (Eurobarometer 2006, Finucane, Stevens et al. 2011). However, it is to be discussed whether this might also be due to an overestimation of the predicted energy expenditure. The energy equations that are currently being used for the calculation and therefore the individual energy recommendations, have been criticised for decades for their tendency to overestimate the energy expenditure (Siervo, Boschi et al. 2003, Frankenfield, Roth-Yousey et al. 2005, Anderson, Sylvia et al. 2014).

Therefore we compared the results of eight different energy equations with the actual energy intake of 102 subjects, who kept a food diary over a period of two weeks. Since mostly women participate in weight reduction programs and consider themselves more health-conscious, we focused on this gender (Siervo, Boschi et al. 2003, Eurobarometer 2010, Thoma, Hediger et al. 2012). Energy equations considered for the comparison were Harris-Benedict, Schofield, Owen, Mifflin-St. Jeor, Müller, Livingston, Oxford and the area mass index (AMI) (Figure 1) (Harris and Benedict 1919, Schofield 1984, Owen, Kavle et al. 1986, Mifflin, St Jeor et al. 1990, Müller, Bosy-Westphal et al. 2004, Henry 2005, Livingston and Kohlstadt 2005, Schlich, Schumm et al. 2010). The AMI has not been published yet and is only allowed to be used exclusively by the Online weight management program “slim dynamics”.

Harris-Benedict:

$$\text{BMR (kcal)} = 655 + (9.563 \times \text{weight in kg}) + (1.850 \times \text{height in cm}) - (4.676 \times \text{age in years})$$

Schofield:

Schofield I - weight only:

$$\text{aged 18 – 30 years: RMR (kcal)} = (14.7 \times \text{weight in kg}) + 496$$

$$\text{aged 31 – 60 years: RMR (kcal)} = (8.7 \times \text{weight in kg}) + 829$$

$$\text{aged >60 years: RMR (kcal)} = (10.5 \times \text{weight in kg}) + 596$$

Schofield II - weight and height:

$$\text{aged 18 – 30 years: RMR (kcal)} = (13.3 \times \text{weight in kg}) + (334 \times \text{height in m}) + 35$$

$$\text{aged 31 – 60 years: RMR (kcal)} = (8.7 \times \text{weight in kg}) - (25 \times \text{height in m}) + 865$$

$$\text{aged >60 years: RMR (kcal)} = (9.2 \times \text{weight in kg}) + (637 \times \text{height in m}) - 302$$

Owen:

$$\text{RMR (kcal)} = 795 + (7.18 \times \text{weight in kg})$$

Mifflin-St. Jeor:

$$\text{RMR (kcal)} = (10 \times \text{weight in kg}) + (6.25 \times \text{height in cm}) - (5 \times \text{age in years}) - 161$$

Müller:

$$\text{RMR (kcal)} = (11 \times \text{weight in kg}) - 3.5 \times \text{age in years} + 764$$

Livingston:

$$\text{RMR (kcal)} = (248 \times \text{weight}^{0.43356} \text{ in kg}) - (5.09 \times \text{age in years})$$

Oxford:

$$\text{RMR (kcal)} = (9.6 \times \text{weight in kg}) + (1.8 \times \text{height in m}) - (4.7 \times \text{age in years}) + 655$$

Figure 1. The different energy equations for females used in this study.

The first energy equation which gained huge popularity was published in 1919 by Harris and Benedict. Today it's still most frequently used in the U.S. Originally, Harris and Benedict developed the equation to diagnose hypo- and hyperthyroidism and not to predict the energy expenditure, however it was used for the latter (Harris and Benedict 1919).

In 1985 the UNU, FAO and WHO assigned Schofield to develop a new equation to be used as a recommendation to calculate the energy expenditure of the population. This equation is still highly recommended by the WHO/FAO and UNU and most frequently used in Europe (Joint and Organization 1985). Schofield published his results in 1985 whereby including a meta-analysis of all published studies about energy equations and energy expenditure since 1919. Schofield established two different equations, the first only including the weight and the second including weight and height (Schofield 1984). However, the same year an overrepresentation of Italian male subjects was criticised, stating that the Italian subjects had a higher BMR per kg body weight than any other group included in the study (Daly, Heymsfield et al. 1985). That again

tends to lead to an overestimation of the energy expenditure of other groups in the population (Daly, Heymsfield et al. 1985). Recently published studies acknowledged this fact (Horgan and Stubbs 2003, Weijs and Vansant 2010, Frankenfield 2013), while others stated that the Schofield equation, particularly the one for women is most accurate (Rosado, de Brito et al. 2014).

Also in 1985 Owen et al. published their energy equation. They measured the resting metabolic rate (RMR) of 60 men and 44 women by indirect calorimetry (Owen, Kavle et al. 1986, Owen, Holup et al. 1987). Recent studies claimed that the energy equation developed by Owen et al. is one of the most accurate ones (Siervo, Boschi et al. 2003, Weijs and Vansant 2010, Frankenfield 2013).

After a five year investigation period Mifflin, St. Jeor et al. published their energy equation in 1990. They also measured RMR by indirect calorimetry of 251 men and 247 women. Since equations so far did not consider overweight or obese subjects, they paid special attention to this group (Mifflin, St Jeor et al. 1990). Recent studies acknowledged their effort, stating that the equation is most accurate not only for normal weight, but also for overweight and obese people (Frankenfield, Rowe et al. 2003, Weijs and Vansant 2010, Frankenfield 2013).

The largest German study so far was published by Müller et al. in 2004. Of 2528 subjects the body composition was measured by bioelectrical impedance analysis (BIA) or skinfold- thickness measurements and the resting energy expenditure (REE) by indirect calorimetry in seven different hospitals in Germany (Müller, Bosy-Westphal et al. 2004). One year later, in 2005, Livingston and Kohlstadt, as well as Henry published their individual energy equations. Both studies combined a meta-analysis of the data points of former studies with separate measurements of the RMR by indirect calorimetry (Henry 2005, Livingston and Kohlstadt 2005). Livingston and Kohlstadt used all data points of the studies of Harris and Benedict and Owen (Livingston and Kohlstadt 2005). Henry used as well all data points of Harris and Benedict and in addition the data from Schofield, while excluding all Italian subjects from the database. Since Henry's studies were done at the University of Oxford, the equation is mainly referred to as Oxford equation (Henry 2005). The last three mentioned equations by Müller et al., Livingston and Kohlstadt and Henry all tend to have a similar accuracy, such as Owen and Mifflin-St. Jeor (Frankenfield, Roth-Yousey et al. 2005, Weijs and Vansant 2010, Frankenfield 2013).

One of the most recent developed energy equations is the area mass index (AMI), published in 2010 by Schlich et al. Different from the former mentioned studies, the body surface was measured and not the BMR or RMR. The AMI is based on the theory, that a greater body surface

is linked to a greater heat exchange with the environment, which predicts that the body is able to burn more energy while keeping a steady weight. Due to the higher heat exchange lean and tall individuals tend to have a lower amount of body fat. Small and compact individuals on the contrary, have a smaller heat exchange with the environment and furthermore a higher isolating effect, due to the body fat (Schlich, Schumm et al. 2010, Schlich 2014). So far the AMI has not been investigated.

In the present study the eight different energy equations were compared and the following questions considered: (1) Does the estimated energy expenditure differ from the actual energy intake? (2) Does that lead to a weight change during the period of one month? (3) Which impact has physical activity? (4) Which energy equation is the most adequate one for the adult female population? (5) Is there a difference between old and young or lean and overweight subjects?

Methods and Subjects

Subjects were recruited between February and June 2015 in Austria, Switzerland and Germany. All women aged between 18 and 65 years were allowed to participate. The exclusion criteria were pregnancy or lactation, the intake of corticoids and the following diseases: thyroid disease, Diabetes mellitus, cancer and cardiovascular disease. At the end of June the last of 104 participants was enrolled. Two subjects had to be excluded since they did not want to maintain the dietary record.

All subjects were invited to individual examinations, where they had to complete a questionnaire about their history of health, diet and physical activity. Furthermore it was explained how they should complete the records on diet and physical activity. Weight, height and circumferences of hip, waist and neck were measured a final appointment one month later fixed.

Within the second face to face examination the completed diaries were returned, screened and any questions about special events during the examination period were clarified. Height, weight and circumferences of hip, waist and neck were determined again.

To ensure a diversity in the study population, the group was divided into eight subgroups, shown in figure 2. All women were classified into 'young' (under 30 years of age) and 'old' (30 years of

age and older) and four different clothes sizes (small, medium, large and extra-large). Since the clothes sizes can vary between stores, the groups were defined by the hip circumference measured during the first examination. The reference was a table containing all circumferences for different sizes, which is also being used in the German clothing industry (Verband 1983).

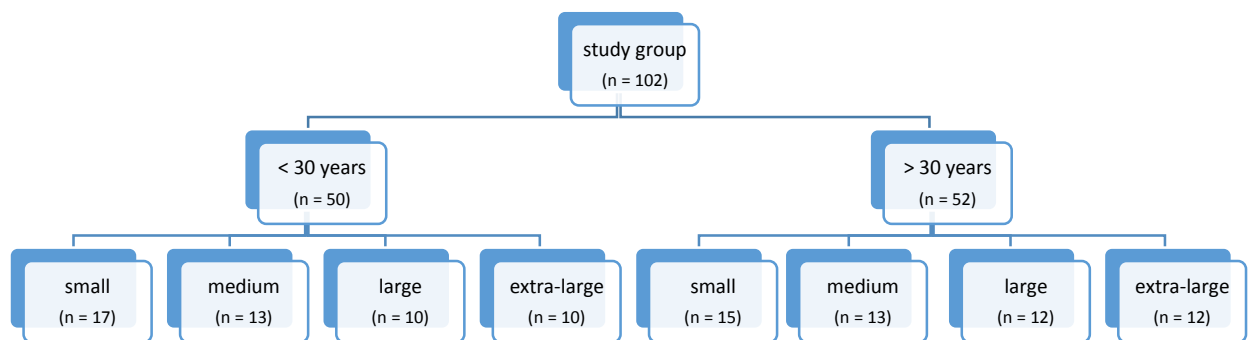


Figure 2. Study group and subgroups.

7-day-food-diary

Every subject was obliged to note all consumed foods for one week in an individual diary starting the day after the first examination. Preferably the food was weighted, but also household measures were accepted. After the subjects completed the first week of the dietary record, they had to either return it by post or to deliver it personally. After a two week break each woman was reminded to start her second week of the diary, which finished with the final appointment, where they had to return the completed dietary record.

A 7-day-food-diary was chosen in the present study since it is considered as the ‘goldstandard’ of food recording techniques (Høidrup, Andreasen et al. 2002). Recent studies showed that it’s the most accurate in determining the actual energy and macronutrient intake (Brunner, Juneja et al. 2001). Since it is well known that the accuracy and motivation is going to be reduced after one week, the second study week had to be performed after a two week break (Rebro, Patterson et al. 1998, Høidrup, Andreasen et al. 2002, Kowalkowska, Slowinska et al. 2013). To ensure that the individual food habits were as usual as possible, it was regarded that none of the subjects had special occasions, such as holidays, during their two weeks of participation.

Physical Activity Diary

The dietary record followed two tables to record physical activity. The first part was for the daily physical activities. This included the time spent for sleeping, working, cleaning, getting to and from work, etc. The second part contained all different kinds of leisure time activities such as sports, like running, swimming, cycling, etc., which needed only to be mentioned when done additionally to the every-day-activities.

The physical activity behaviour could be either noted in hours or in minutes. For data analysis the time was multiplied with the metabolic equivalent task (MET) of each activity. All results of the different activities were added up to 24 hours. All missing hours were defined as resting time. So it was possible to compare the physical activity behaviour per day and per hour, without taking weight or BMI in consideration.

With the metabolic equivalent task the energy expenditure of different activities can be compared. It shows the efficiency (or the energy consumption) of different physical activities as a multiplier of the basal metabolic rate. That leads to the following definition: 1 MET is the consumption of one calorie per kilogram body weight per hour (Byrne, Hills et al. 2005).

The MET data was based on the “Compendium of Physical Activities” (Ainsworth, Haskell et al. 1993, Ainsworth, Haskell et al. 2000, Ainsworth, Haskell et al. 2011). Consequently the MET value of every physical activity of every subject could be calculated. The average of every subject’s MET per hour was later used to calculate the individual energy expenditures with the different energy equations, by multiplying with the estimated BMR.

In most studies the Physical Activity Level (PAL) is used so far to calculate the daily physical activity. Though MET and PAL seem to be quite similar at first, they have a different definition. MET always defines the efficiency for a particular physical activity, while the PAL is the result of the division of the Total Energy Expenditure (TEE) and the BMR in a period of 24 hours (Caspersen, Powell et al. 1985, Byrne, Hills et al. 2005, Elliott, Baxter et al. 2014). To evaluate the energy expenditure for every single physical activity, we chose the MET values in the present study, since a more accurate calculation of the physical activity behaviour could be ensured.

Weight diary

Together with the food and physical activity records, the subjects also had to measure their weight every morning before breakfast, with an electronic bathroom scale of the brand Clatronic

and the model PW3368. For most overweight and obese women however, this was the main reason not to participate in the study, since they were uncomfortable to see their weight on a scale every day

Nut.s

For the evaluation of the 7 day dietary records the software program nut.s science was used. It is an Austrian nutrition program for the collection of 24-hour-recalls or dietary records. For the present study the total energy intake (kcal per day) and therefrom the mean for both weeks was taken into consideration.

The database is used for nutrient information and portion sizes was the Bundeslebensmittelschlüssel Version BLS 3.01. The BMR can be calculated according to Harris-Benedict or Schofield. The recommendations of the individual evaluations are based on the ones of the German, Austrian and Swiss Nutrition societies.

BMR predictive equations

The equations from Harris-Benedict, Schofield, Owen, Mifflin-St. Jeor, Müller, Oxford, Livingston and the AMI were used to calculate the BMR and then multiplied with the individual MET per hour. The only exception was the AMI, where the Online program 'slim dynamics' calculated the energy expenditure.

Statistics

For the statistical analysis the software program SPSS for Windows, Version 21.0 was used. The normal distribution of all data was verified by the Kolmogorov-Smirnov-Test. Correlations between the different equations and the total energy intake were calculated with the correlation coefficient by Pearson. The means were either compared by a paired-samples T test or a one-way ANOVA. A p-value of $p < 0.05$ was considered significant.

As mentioned above the study group was divided into different subgroups regarding age and clothes size and also evaluated regarding energy intake, calculated energy requirement and physical activity behaviour.

Underreporting

All data was checked for underreporting by the ratio developed by Goldenberg et al. in 1990, which was also used for the data in the NHANES study. The ratio is defined as the **Energy Intake (EI) : Basal Metabolic Rate (BMR)** and should not be under 1.2 for women with a PAL of 1.6 (Goldberg, Black et al. 1991, Briefel, Sempas et al. 1997, Black 2000). The lowest ratio that could be found in this study was 1.23. Therefore no underreporting due to the ratio by Goldberg could be found and none of the subjects was excluded.

Results

Table 1 describes the total study group of 102 women. The mean age was 37 ± 13 years. The means for weight, height, BMI and WHR were 70.7 ± 14.4 kg, 1.67 ± 0.066 m, 25.2 ± 4.84 and 0.76 ± 0.07 , respectively. The MET per hour of 1.65 ± 0.25 of the study population can be defined as a light intensity physical activity behaviour, which is equivalent to at least one physical workout every week. This is a good representation of an average European female (Eurobarometer 2010).

	MEAN	SD	MINIMUM	MAXIMUM
AGE (in years)	37	13	21	63
WEIGHT (in kg)	70.7	14.4	46.9	111
HEIGHT (in m)	1.67	0.07	1.49	1.83
BMI	25.2	4.8	17.7	39.6
WHR	0.76	0.07	0.63	1.05
MET/H	1.65	0.25	1.23	2.36

Table 1. Description of the total study population (n=102).

The data points describing age, weight and height were measured during the first appointment. Those were also used for the calculation of the energy expenditure by the various equations, which are shown in Table 3. At the final appointment after four weeks, height, weight and the circumferences of hip, waist and neck were measured again. The weight during the study period was constant, with an average of 70.7 ± 14.4 kg at the first, and 70.3 ± 14.1 kg at the second appointment.

From the 102 women 66 were recruited in Austria, 21 in Germany and 15 in Switzerland. Details of these subgroups are shown in Figure 3 and Table 2.

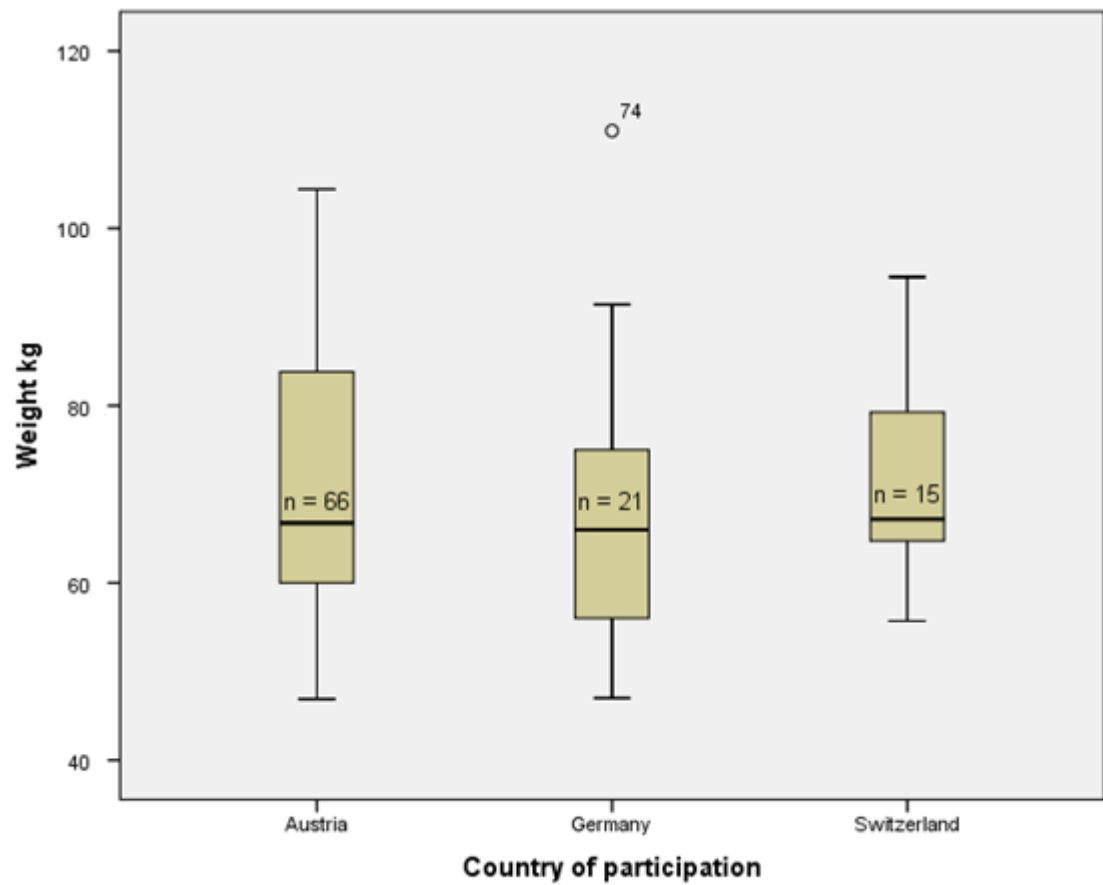


Figure 3. Distribution of the weight between the three subgroups based on their country of participation.

	AUSTRIA (n=66)		GERMANY (n=21)		SWITZERLAND (n=15)	
	MEAN	SD	MEAN	SD	MEAN	SD
AGE (in years)	34	13	40	12	40	10
WEIGHT (in kg)	71.2	14.8	68.6	15	71.4	12
HEIGHT (in m)	1.67	0.07	1.68	0.07	1.69	0.05
BMI	25.5	5.08	24.27	4.42	25.2	4.45
MET/H	1.6	0.23	1.79	0.26	1.62	0.27

Table 2. Description of the three subgroups based on their country of participation.

The mean age of the Austrian study sample is slightly lower, due to the fact that younger subjects were recruited in Vienna, however the difference was not significant.

Table 3 describes the actual energy intake and the estimated energy expenditures of the different energy equations of the total study population. The mean of the real energy intake was 1861 ± 385 kcal/d and therefore always significantly lower ($p < 0.05$) than the predictive energy equations recommended.

	MEAN	SD	MINIMUM	MAXIMUM
HARRIS-BENEDICT (kcal/d)	2424	278	1802	3858
SCHOFIELD I (kcal/d)	2445	515	1717	4042
SCHOFIELD II (kcal/d)	2447	512	1729	3973
OWEN (kcal/d)	2147	407	1517	3391
MIFFLIN-ST. JEOR (kcal/d)	2329	494	1685	3707
MÜLLER (kcal/d)	2332	483	1669	3820
LIVINGSTON (kcal/d)	2272	448	1671	3642
OXFORD (kcal/d)	2379	490	1699	3783
AMI (kcal/d)	2116	285	1378	3081
ENERGY INTAKE (kcal/d)	1861	385	1021	3067

Table 3. Comparison of the different energy equations with the actual energy intake of the total study population (n=102).

Comparing all energy equations with the assessed energy intake it can be shown that the energy intake is significant lower ($p<0.05$) than all the equations recommend.

Furthermore all equations correlate significantly ($p<0.05$) between each other, which acknowledges their similar methods of development and the fact that some of the later studies included previous data points into their calculations.

Since the energy equation tend to overestimate the energy expenditure especially in overweight and obese individuals, the study population was divided into four subgroups. The classification was done by the subjects' clothes size into small, medium, large and extra-large.

In Figures 4, 5 and 6 weight, BMI and the energy intake divided into the four subgroups can be observed. While Figures 4 and 5 show an increase of the weight and the BMI from sizes small to extra-large ($p<0.05$), the mean energy intake was similar in all four subgroups. The detailed

information on the total energy intake and the energy recommendations are summarized in Table 4.

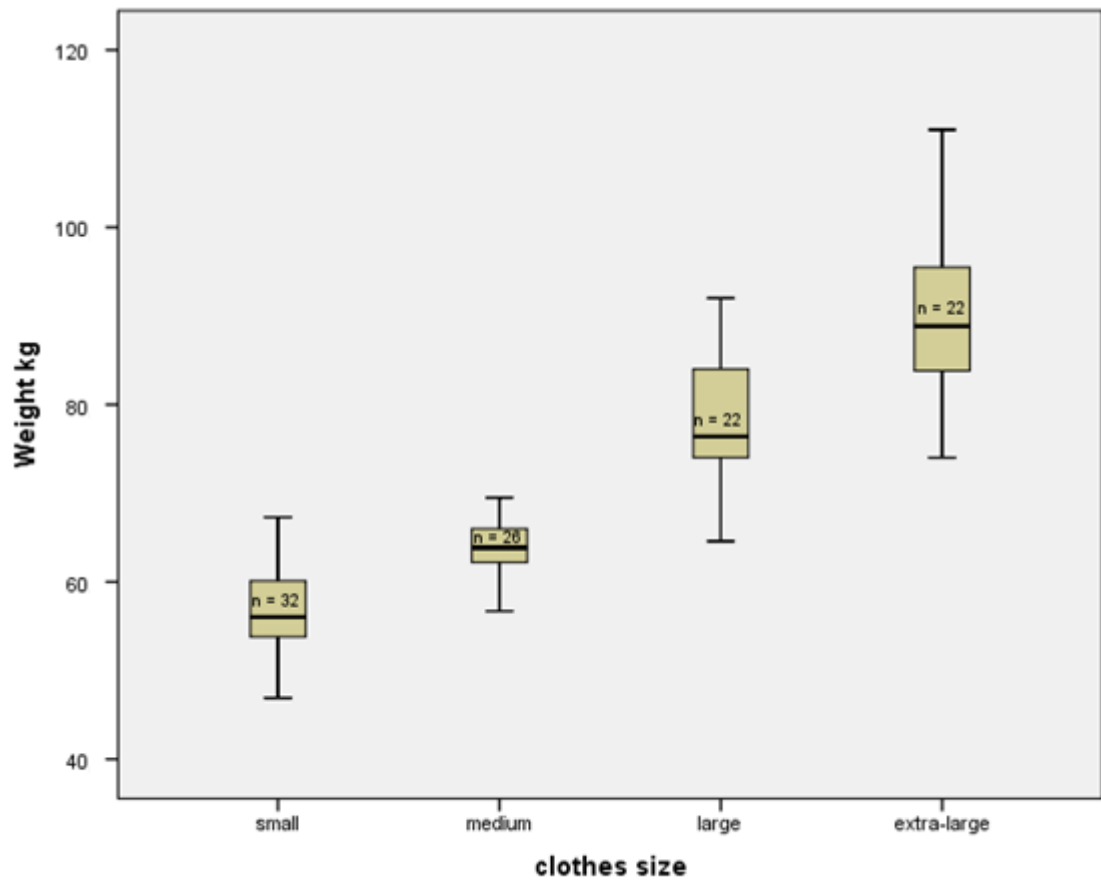


Figure 4. Distribution of the weight between the four subgroups based on their clothes size.
(S < M < L < XL; $p < 0.05$)

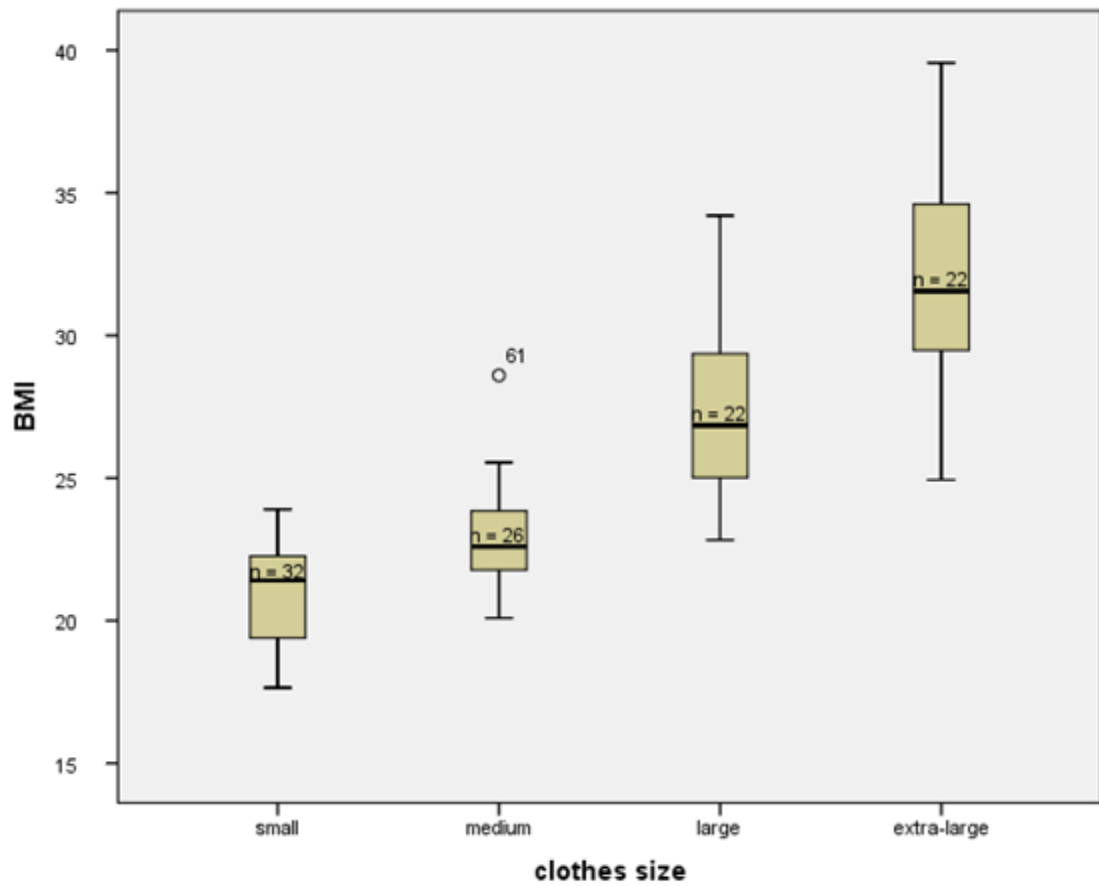


Figure 5. Distribution of the BMI between the four subgroups based on their clothes size.
(S < M < L < XL; $p < 0.05$)

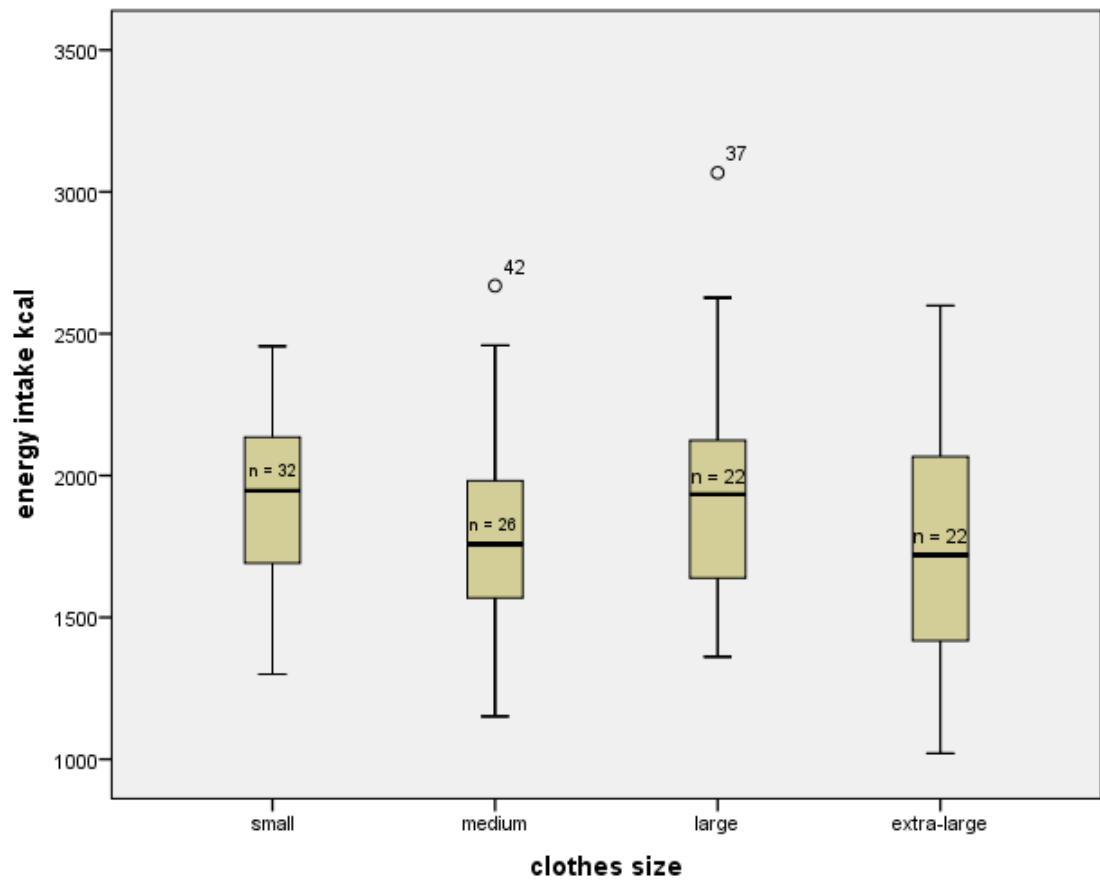


Figure 6. Distribution of the daily energy intake between the four subgroups based on their clothes size.
(S = M = L = XL; n.s.)

	SMALL (n=32)		MEDIUM (n=26)		LARGE (n=22)		EXTRA-LARGE (n=22)	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
HARRIS-BENEDICT (kcal/d)	2209 ^{*cd}	332	2166 ^{*cd}	253	2598 ^{*ab}	453	2867 ^{*ab}	516
SCHOFIELD I (kcal/d)	2181 ^{*cd}	338	2162 ^{*cd}	261	2650 ^{*ab}	467	2958 ^{*ab}	532
SCHOFIELD II (kcal/d)	2192 ^{*cd}	338	2167 ^{*cd}	261	2649 ^{*ab}	474	2947 ^{*ab}	534
OWEN (kcal/d)	1975 ^{cd}	290	1933 ^{cd}	239	2287 ^{*ab}	383	2510 ^{*ab}	442
MIFFLIN-ST. JEOR (kcal/d)	2085 ^{cd}	327	2071 ^{*cd}	271	2525 ^{*ab}	457	2794 ^{*ab}	530
MÜLLER (kcal/d)	2088 ^{cd}	317	2066 ^{*cd}	238	2518 ^{*ab}	445	2817 ^{*ab}	499
LIVINGSTON (kcal/d)	2063 ^{cd}	316	2032 ^{*cd}	229	2441 ^{*ab}	426	2688 ^{*ab}	476
OXFORD (kcal/d)	2145 ^{*cd}	326	2119 ^{*cd}	277	2573 ^{*ab}	450	2833 ^{*ab}	530
AMI (kcal/d)	2142 [*]	244	2093 [*]	270	2206	336	2013 [*]	287
ENERGY INTAKE (kcal/d)	1899	325	1788	373	1978	405	1777	442

Table 4. Comparison of the different energy equations with the actual energy intake divided into four subgroups by size.

***... p<0.05 compared to the energy intake in the individual subgroup**

a... p<0.05 compared to the subgroup 'small'

b... p<0.05 compared to the subgroup 'medium'

c... p<0.05 compared to the subgroup 'large'

d... p<0.05 compared to the subgroup 'extra-large'

The average energy intake ranged between 1777 kcal (in the extra-large group) and 1978 (in the large group). The energy intake was not significantly different between the subgroups ($p=0.3$). In the S-group Owen, Mifflin-St. Jeor, Müller and Livingston did not differ significantly from the recorded energy intake. The same applies for Owen in the M-group. In the XL-group all equations show a significant difference, while in the L-group the AMI is the only one without a significant difference to the recorded energy intake.

The AMI is the only equation, with no increased estimated energy intake with increasing clothes size. In all the other recommendations the S- and the M-group differ significantly from the L- and the XL-group and vice versa. However, there are no significant differences between the S- and M-subgroup, as well as the L- and XL-subgroup.

In all groups most of the equations recommended a higher energy expenditure than the diary based energy intake. While all energy equations are in a quite similar range in the S- and M-group, a large difference can be found in the L- and XL-group. While Schofield calculated an average energy expenditure of almost 3000 kcal/d in the XL-group, the AMI recommends approximately 2000 kcal/d, which is even less than in the S-group. While the AMI-recommendation is significantly different to the diary based energy intake in the XL-group ($p < 0.05$), it is the only equation which is not significantly different from the energy intake in the L-group. Therefore the AMI tends to be the most adequate for the L- and XL- subgroups, with an overestimation of less than 15%. Some of the other equations overestimated the energy expenditure by up to 30% in the L-group, and even 60% in the XL-group. The only equation which seems quite similar to the AMI is the one developed by Owen. It has an overestimation of around 16% in the L-group and 41% in the XL-group. This is furthermore acknowledged by the fact, that no significant difference can be found in the L-group between Owen and the AMI ($p = 0.36$).

A lot of equations were established with fairly young study population and without considering appropriate numbers of older subjects. This is one of the strengths of the present study, where the study population was further divided into two subgroups. The first subgroup included all younger women under the age of 30 years (50 subjects) and the second subgroup all older women at or above the age of 30 years (52 subjects). All data is shown in Table 5.

	AGE UNDER 30 YEARS (n=50)		AGE OVER 30 YEARS (n=52)	
	MEAN	SD	MEAN	SD
HARRIS-BENEDICT (kcal/d)	2383*	479	2463*	479
SCHOFIELD I (kcal/d)	2389*	555	2499*	473
SCHOFIELD II (kcal/d)	2395*	549	2497*	473
OWEN (kcal/d)	2043 ^a	393	2247 ^{*b}	398
MIFFLIN-ST.JEOR (kcal/d)	2299*	496	2359*	495
MÜLLER (kcal/d)	2268*	476	2394*	487
LIVINGSTON (kcal/d)	2242*	449	2299*	450
OXFORD (kcal/d)	2325*	510	2431*	470
AMI (kcal/d)	2136*	293	2096*	279
ENERGY INTAKE (kcal/d)	1852	398	1871	376

Table 5. Comparison of the different energy equations and the actual energy intake divided into two subgroups by age.

***... p<0.05 compared to the energy intake in the individual subgroup**

a... p<0.05 compared to the subgroup 'young'

b... p<0.05 compared to the subgroup 'old'

Compared with the diary based energy intake, all equations overestimated the energy expenditure significantly ($p<0.05$). There is no significant difference of the actual energy intake between the younger and the older subgroup ($p=0.81$), as well as between most of the results of the different energy equations. The only exception is the Owen-equation, which recommends significantly less energy for the younger group than for the older subgroup ($p<0.05$).

In the younger subgroup, Owen tends to be the most accurate, with an overestimation of only 10%. In the older group however, the AMI is more adequate, with an overestimation of approximately 12%, while Owen overestimates the energy expenditure by 20%. All other equations calculated a much higher energy expenditure with an overestimation of around 25%

in the younger group, and even 30% in the older group. In Figure 7 it can be seen that even though the energy equations recommend a higher energy expenditure in the older group, the diary based energy intakes of both groups are quite similar.

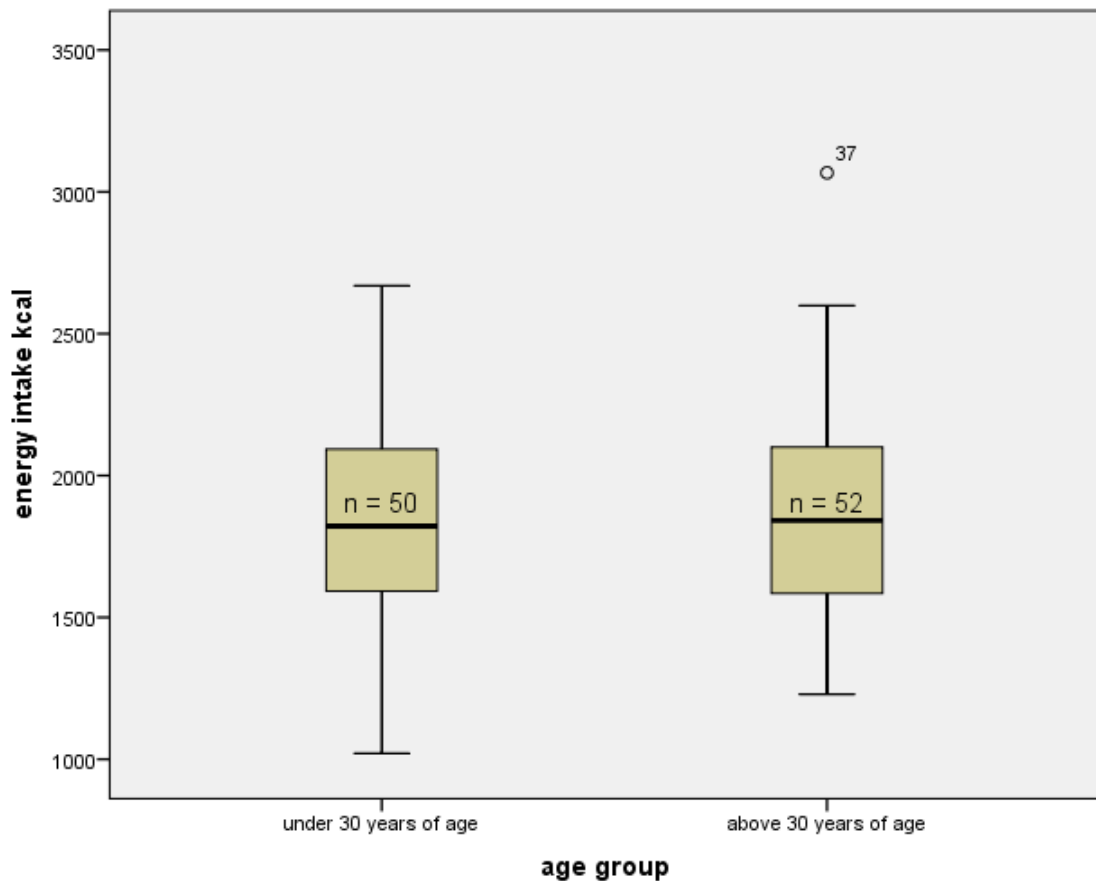


Figure 7. Distribution of the daily energy intake between the two subgroups based on their age. (under 30 years = 30 year and older; n.s.)

The study population was further subdivided into eight subgroups due to age and clothes size. All subgroups comprised with at least ten subjects. Figure 8 shows the weight of the participants, while Figure 9 shows the energy intake. Again, it can be seen, that even though the weight increases between the different subgroups, the energy intake remains in a similar range.

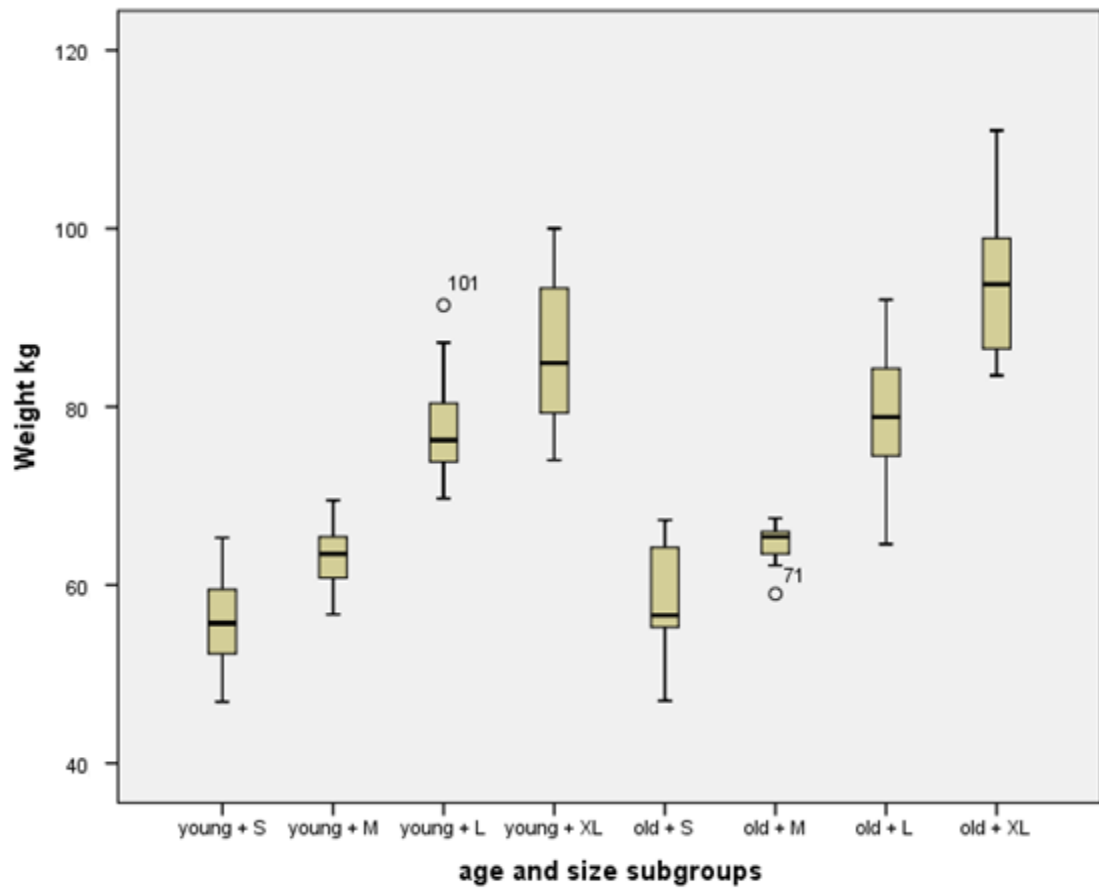


Figure 8. Distribution of the weight between the eight subgroups based on their age and clothes size.
(S < M < L < XL for both age groups; $p < 0.05$)

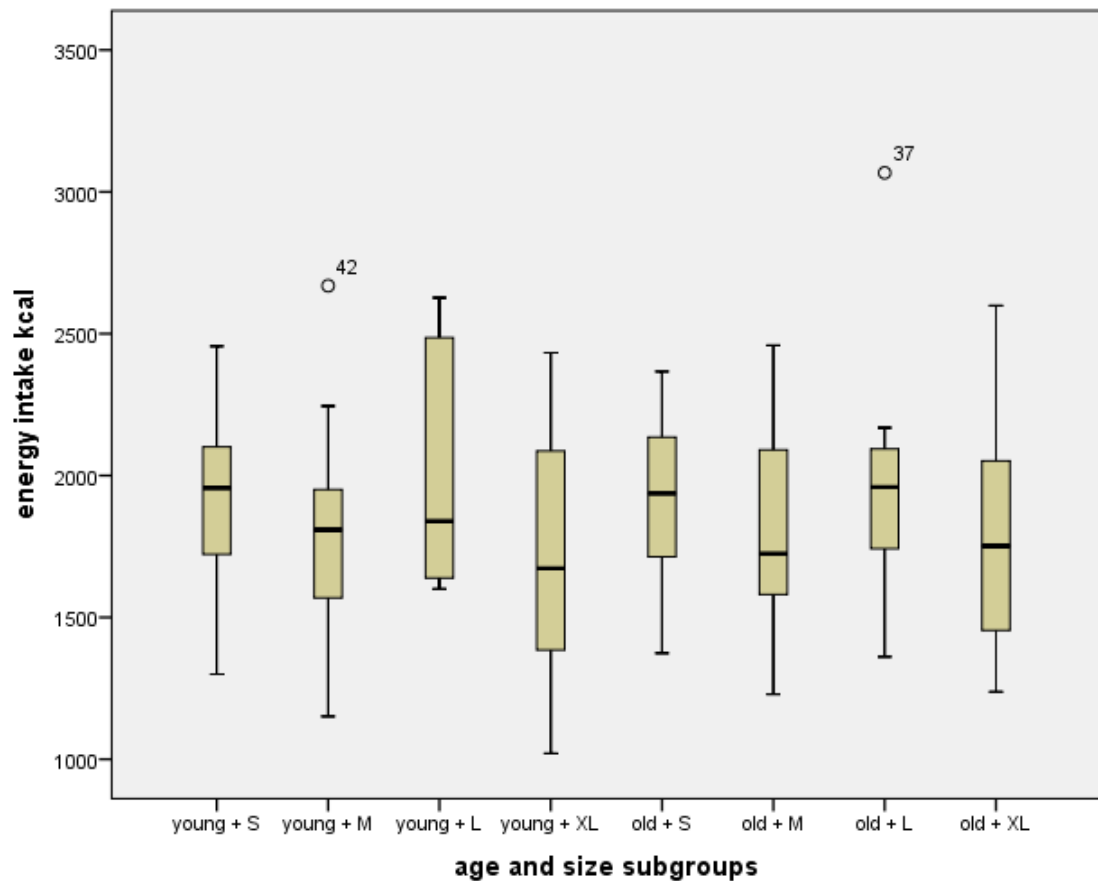


Figure 9. Distribution of the daily energy intake between the eight subgroups based on their age and clothes size.

(S = M = L = XL for both age groups; n.s.)

Further background information on all eight subgroups can be found in Table 6 and 7. Table 6 comprises the younger and Table 7 the older subgroups.

	YOUNG + SMALL (n=17)		YOUNG + MEDIUM (n=13)		YOUNG + LARGE (n=10)		YOUNG + X-LARGE (n=10)	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
HARRIS- BENEDICT (kcal/d)	2209 ^{dh}	410	2091 ^{*cdh}	230	2689 ^{*b}	343	2753 ^{*abe}	570
SCHOFIELD I (kcal/d)	2122 ^{cdh}	422	2053 ^{cdh}	239	2760 ^{*ab}	389	2906 ^{*abef}	620
SCHOFIELD II (kcal/d)	2145 ^{cdh}	424	2062 ^{cdh}	253	2771 ^{*ab}	403	2878 ^{*abef}	618
OWEN (kcal/d)	1926 ^h	358	1798 ^{dgh}	189	2273 ^{bc}	281	2329 ^{*b}	473
MIFFLIN- ST.JEOR (kcal/d)	2097 ^{cdh}	399	2000 ^{cdh}	250	2642 ^{*ab}	376	2685 ^{*abef}	575
MÜLLER (kcal/d)	2071 ^{cdh}	392	1978 ^{cdgh}	215	2574 ^{*ab}	332	2672 ^{*abef}	555
LIVINGSTON (kcal/d)	2066 ^{dh}	387	1974 ^{cdh}	211	2533 ^{*b}	308	2601 ^{*abef}	528
OXFORD (kcal/d)	2123 ^{cdh}	412	2014 ^{cdh}	257	2672 ^{*ab}	391	2726 ^{*abe}	585
AMI (kcal/d)	2159 [*]	250	2079 [*]	289	2289	393	2015	204
ENERGY INTAKE (kcal/d)	1892	353	1797	387	1988	407	1718	477

Table 6. Comparison of the different energy equations and the actual energy intake divided into eight subgroups by age and size.

*** ... p<0.05 compared to the energy intake in the individual subgroup**

a... p<0.05 compared to the subgroup 'young and small'

b...p<0.05 compared to the subgroup 'young and medium'

c... p<0.05 compared to the subgroup 'young and large'

d... p<0.05 compared to the subgroup 'young and extra-large'

e... p<0.05 compared to the subgroup 'old and small'

f... p<0.05 compared to the subgroup 'old and medium'

g... p<0.05 compared to the subgroup 'old and large'

h... p<0.05 compared to the subgroup 'old and extra-large'

Comparing the energy intake and the energy equations in the eight subgroups it can be seen that all equations calculate a higher energy expenditure than the recorded energy intake, which differs not significantly between the eight subgroups (p=0.7). The AMI is the only calculated one, which is also not significantly different between the eight subgroups (p=0.41).

In the 'young + small' subgroup, the AMI is the only equation which is significantly different to the consumed energy ($p < 0.05$). The same is true for the AMI and the Harris-Benedict equation in the 'young + medium' group ($p < 0.05$). In the subgroup 'young + large' however, the AMI ($p = 0.2$) and the Owen equation ($p = 0.14$) are the only ones to be not significantly different to the actual energy intake. While all energy equations are significantly higher ($p < 0.05$) than the recommended energy intake in the group 'young + extra-large', the AMI is the only one which not differs significantly ($p = 0.14$) and is therefore the most accurate one.

The variances which could be observed between the different subgroups based on the subjects' clothes size, are again acknowledged. Mostly all energy equations recommend less in the two subgroups 'young + small' and 'young + medium' compared to the groups 'young + large' and 'young + extra-large' (Table 6).

Especially in the L- and XL-groups an overestimation of the energy intake, in some cases of more than 1000 kcal, can be seen. This endorses the results in the overweight and obese subgroups before. In the S- and M-groups the equation of Owen is most accurate. In the Group 'Young + Medium' the average energy intake is 1797 kcal, while the mean of the Owen equation is almost the same, with 1798. In the L- and XL-groups the AMI was the most adequate equation, with an overestimation of only 17% at highest. Furthermore it is acknowledged by the fact, that the AMI is also not significantly different to the reported energy intake. Owen overestimated the energy intake by 14% (in the L-group) and 36% (in the XL-group), which is still more accurate than an overestimation of sometimes more than 65% by other equations.

	OLD + SMALL (n=15)		OLD + MEDIUM (n=13)		OLD + LARGE (n=12)		OLD + X-LARGE (n=12)	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
HARRIS-BENEDICT (kcal/d)	2209 ^{*dh}	228	2242 ^{*h}	261	2522 [*]	531	2962 ^{*abef}	470
SCHOFIELD I (kcal/d)	2248 ^{*dh}	202	2272 ^{*dh}	243	2558 [*]	522	3001 ^{*abef}	471
SCHOFIELD II (kcal/d)	2245 ^{*dh}	206	2272 ^{*dh}	232	2548 [*]	520	3004 ^{*abef}	473
OWEN (kcal/d)	2031 ^h	182	2068 ^{*h}	210	2298 ^b	465	2661 ^{*abef}	367
MIFFLIN-ST.JEOR (kcal/d)	2071 ^{cdh}	233	2143 ^{*dh}	282	2427	511	2885 ^{*abef}	496
MÜLLER (kcal/d)	2107 ^{dh}	213	2153 ^{*dh}	236	2470 ^b	531	2938 ^{*abef}	433
LIVINGSTON (kcal/d)	2060 ^{dh}	222	2090 ^{*dh}	239	2364	504	2760 ^{*abef}	438
OXFORD (kcal/d)	2169 ^{*dh}	202	2224 ^{*dh}	265	2490	494	2923 ^{*abef}	487
AMI (kcal/d)	2123	244	2107 [*]	260	2136	278	2012	351
ENERGY INTAKE (kcal/d)	1906	302	1780	375	1971	422	1826	426

Table 7. Comparison of the different energy equations with the actual energy intake divided into eight subgroups by age and size.

***... p<0.05 compared to the energy intake in the individual subgroup**

a... p<0.05 compared to the subgroup 'young and small'

b...p<0.05 compared to the subgroup 'young and medium'

c... p<0.05 compared to the subgroup 'young and large'

d... p<0.05 compared to the subgroup 'young and extra-large'

e... p<0.05 compared to the subgroup 'old and small'

f... p<0.05 compared to the subgroup 'old and medium'

g... p<0.05 compared to the subgroup 'old and large'

h... p<0.05 compared to the subgroup 'old and extra-large'

In the older subgroups the estimated energy expenditure is again higher than the recorded energy intake. In the subgroup 'old + extra-large' the AMI is once more the only equation which was not significantly different to the documented energy intake (p=0.17). Harris-Benedict, both Schofield equations and Oxford are the only four significantly higher (p<0.05) to the energy

intake in the group 'old + small'. All energy equations differ significantly ($p < 0.05$) from the energy intake in the group 'old + medium'. In the subgroup 'old + large' only Harris-Benedict and Schofield are significantly higher ($p < 0.05$) compared to the intake data.

In the two subgroups 'old + small' and 'old + medium' again a significant difference ($p < 0.05$) to mostly all equations in both extra-large subgroups can be found (Table 7). Unexpectedly most estimated energy expenditures in the 'old + large' group are not significantly different between the other subgroups. The only exceptions are Owen and Müller, which are both significantly higher ($p < 0.05$) compared to the subgroup 'young + medium'. The predicted energy expenditures in the subgroup 'old + extra-large' are significantly different ($p < 0.05$) to both small and medium groups, independent of the age groups.

The L- and XL-subgroups are also for the older women the two groups which show the highest overestimation, with a recommendation of sometimes 3000 kcal/d by for example the Schofield equation. In the S- and M-groups the equation of Owen is again the most adequate one. In the L- and especially the XL-group the AMI was the most accurate equation, with an overestimation of 8% in the L- and 10% in the XL-group. Owen and Livingston show at least in the L-group a lower overestimation to the other equations with 17% and 20% respectively, while they all overestimate the recorded energy intake by at least 46% in the XL-group.

Furthermore the physical activity of the study population was analysed (Table 8). There was no significant difference in the groups when considering respective by size and age ($p = 0.2$), only between the subgroups 'young + medium' and 'old + extra-large' ($p < 0.05$).

	MEAN	SD	MINIMUM	MAXIMUM
SMALL (n=32)	1.64 ^b	0.23	1.23	2.36
MEDIUM (n=26)	1.54 ^a	0.18	1.33	2.00
LARGE (n=22)	1.68 ^b	0.26	1.37	2.33
EXTRA-LARGE (n=22)	1.74 ^b	0.31	1.31	2.35
UNDER 30 YEARS (n=50)	1.59	0.25	1.23	2.36
30 YEARS AND OLDER (n=52)	1.70	0.24	1.37	2.35

**Table 8. Physical activity behaviour (in MET/h) divided into two and four subgroups by size and by age. (a < b; p<0.05)
(under 30 years < 30 years and older; p<0.05)**

Unexpectedly the XL-subgroup was the most active one. However, a significant difference could only be found between the M-subgroup ($p<0.05$) and the other ones, showing that the M-group was the least active one. Furthermore the women at or over 30 years of age were significantly more active than the younger women ($p<0.05$).

Table 9 summarizes the percentages of overestimation. It shows that the equation by Harris and Benedict and the ones by Schofield have the highest overestimation. Still, they're the ones used most frequently. Moreover it can be seen, that the overestimation increases with increasing clothes size. The only exception seems to be the AMI, which is even more accurate for the women in the L- and XL-subgroups.

	STUDY (n=102)	GROUP: S (n=32)	GROUP: M (n=26)	GROUP: L (n=22)	GROUP: XL (n=22)
HARRIS-BENEDICT	30%	16%	21%	31%	61%
SCHOFIELD I	31%	15%	21%	34%	66%
SCHOFIELD II	31%	15%	21%	34%	66%
OWEN	15%	4%	8%	16%	41%
MIFFLIN-ST. JEOR	25%	10%	16%	28%	57%
MÜLLER	25%	10%	16%	27%	59%
LIVINGSTON	22%	9%	14%	23%	51%
OXFORD	28%	13%	19%	30%	59%
AMI	14%	13%	17%	11%	13%

Table 9. Overestimation (in %) of the different energy equations for the total study population and for the four subgroups based on their clothes size.

Discussion

The results of the present study show that all evaluated energy equations significantly overestimate the energy expenditure and give recommendations that are sometimes 60% higher than the recorded energy intake. Comparing the eight equations, Owen and the AMI are most accurate. For women wearing clothes size small Livingston, Mifflin-St. Jeor and Müller are also still adequate to estimate energy expenditure (Table 4). But the higher the clothes size, the higher the overestimation of the energy intake. The only exception is the AMI, which does not show a significant difference between the subgroups divided by size. Hence, the AMI is the most accurate for the L- and XL-groups. The most frequently used equations by Harris-Benedict and Schofield overestimate the energy expenditure the most.

For women wearing sizes large and above, the AMI is the most accurate equation compared to the other ones. It still overestimates the energy expenditure by 10 – 15%, but that is low compared to an overestimation of sometimes 60% (e.g. Harris-Benedict and Schofield). Furthermore the AMI is the only equation in the L-group, which is not significantly different ($p=0.06$) to the recorded energy intake (Table 4). Owen builds the gap between the AMI and the other six equations with an overestimation of 41% at most (Table 9).

The reason for the higher accuracy of the equations of Owen, Mifflin-St. Jeor, Müller and the AMI could be the fact that they recruited their own study population instead of using some, or

even all data points of former studies (e.g. Schofield used data from Harris-Benedict). Therefore they did not overtake bias that may have occurred during the investigation period of the previous studies (Harris and Benedict 1919, Schofield 1984, Owen, Kavle et al. 1986, Mifflin, St Jeor et al. 1990, Müller, Bosy-Westphal et al. 2004, Frankenfield, Roth-Yousey et al. 2005, Henry 2005, Livingston and Kohlstadt 2005, Schlich, Schumm et al. 2010).

One of the main points of the criticism surrounding the equation of Harris and Benedict is the very lean and young study population. The mean data of the here presented study gives a good reflection of the average European population nowadays, as shown in Table 1. Compared to the study of Harris and Benedict, with a mean age of 31 ± 14 years and a mean weight of 56.5 ± 11.5 kg, which was representative for the female population in 1919 (Harris and Benedict 1919), today it is quite different. The mean age, weight, height and BMI for females in Europe are 42 years of age, 72.2 kg, 1.69 m and 25 kg/m^2 (Eurobarometer 2006, Yearbook 2012), and therefore it's questionable if the study population and the consequential equation of Harris and Benedict can be adjusted to this situation.

The study population (Table 1) represents quite well the average female population in the German speaking countries (Eurobarometer 2006). Only the average age of the study sample is five years under the mean age of the female population. Since the recruiting process took mainly part at the University of Vienna a lot of female students signed up for the study and were really motivated to participate. Most of them are young and lowered therefore the average age, which is also acknowledged by the insignificantly lower mean age in the Austrian group (Table 2).

The comparison of the energy expenditures of the eight different equations and the diary based energy intake (Table 3) shows that the recorded energy intake is always at least 15% lower than the estimated energy expenditure. Therefore the Goldberg method was applied to ensure that no underreporting would bias the data. The Goldberg standard is described as the ratio of the actual energy intake (EI) and the Basal metabolic rate (BMR). An average women with a PAL of 1.6 and a Goldberg ratio of less than 1.2 can be defined as an underreporter (Goldberg, Black et al. 1991, Black 2000, Livingstone, Robson et al. 2003). In the present study however, the lowest score was 1.23 and therefore no subject was excluded due to underreporting.

Since the results cover 14 days of dietary protocols for every single women it is very likely that the mean energy intake gives a good representation of the average food intake of the particular subject. So far no dietary instrument can capture the energy intake of a subjects with complete accuracy, but the dietary record and the weight protocol tend to be the most adequate (Brunner,

Juneja et al. 2001, Day, McKeown et al. 2001). Even though the weight protocol has a higher precision, it is also associated to lower the compliance of the participating subjects, since they have to weight everything they eat (Riboli, Elmståhl et al. 1997, Willett 2001). Therefore the dietary record seemed to be the most suitable to assess the actual energy intake. The subjects completed the diary by using household measures, the exact amount or even document the used recipe. Furthermore pictures of ten different dishes were added, where the subjects could compare their food and indicate how much their portion related to the amount shown in the picture. This already proved to be successful in the EPIC study (Day, McKeown et al. 2001). To not reduce the motivation of the subject, the food diary was kept quite simple, while still maintaining the highest accuracy as possible. So even if underreported for one day, which is very likely, it can still be balanced by the other 13 days (Biltoft-Jensen, Matthiessen et al. 2009).

To find an appropriate study sample that would represent the female population was quite challenging during the recruiting period. While lean and young women were eager to take part in this study immediately, especially young overweight and obese women were not. Therefore the recruitment process took longer than expected. The women wearing L and XL were really interested in a healthy lifestyle with 'good food' and a high physical activity behaviour, which is also acknowledged in the comparison of the average MET/h of the different groups (Table 8). It sometimes seemed that they were more persistent in maintaining their even higher weight with healthy food and a lot of physical activity than the subjects wearing sizes small and medium.

However all subjects participating in such a study are more interested in health related topics than others (Rothman and Greenland 1998, Morton, Cahill et al. 2006), since one month of participation requires a lot of time and motivation. Furthermost most women wanted detailed background information on their diet and nutritional status. Their individual results and the inclusion of the present study into a master thesis seemed to influence most women to complete the diaries as detailed and appropriate as possible. Some stated that they felt a 'sense of obligation' to do a good job, increasing the compliance of the study population (Morton, Cahill et al. 2006, Teschke, Marino et al. 2010, Slegers, Zion et al. 2015).

However most energy equations still tend to highly overestimate the real energy intake. Especially the most frequently used equations by Harris-Benedict and Schofield show an overestimation of sometimes 60%, and they are still being used for most weight reduction programs and are highly recommended by the WHO (Joint and Organization 1985). Also, the study and equation of Mifflin, St. Jeor et al. which was particularly vigilant of recruiting

overweight and obese subjects (Mifflin, St Jeor et al. 1990), has an overestimation of 30% in our group of subjects wearing clothes sizes L and XL.

Figures 4 and 5 show the steady increase of the weight in the four subgroups based on the subjects' clothes size and BMI. For decades the BMI has been used to determine the amount of body fat and the associated health risks (Frankenfield, Rowe et al. 2001), yet there tend to be limitations in its accuracy (Pasco, Nicholson et al. 2012). The WHR seems to be more suitable to predict the body composition for the average woman (Janssen, Heymsfield et al. 2002, Thoma, Hediger et al. 2012). Since the WHR is associated to the clothes size, due to hip and waist measurements, the categories based on size may not be the most exact measurement but the most adequate reference point for this study population, because most women measure their own body in clothes size and not in BMI categories (Petroff, Martz et al. 2011).

The two equations which have an estimated energy expenditure closest to the reported energy intake, are the AMI and the equation by Owen et al. While Owen is the most adequate for women wearing sizes small and medium, the AMI is the more accurate for the ones wearing large and extra-large. Even though Owen et al. included many overweight and extremely obese women in their study, they also considered a relatively high percentage of athletes (especially in the women group). This might be the reason for the high accuracy among lean women (Owen, Kavle et al. 1986). The results of the AMI, with an energy expenditure which is lower in the XL- than in the S-group (Table 4), seemed odd at first, but is the most accurate if compared to the reported energy intake. It is further acknowledged by the fact that the AMI is the only equation in the L-group, which is not significantly different ($p=0.06$) to the reported energy intake. The totally different hypothesis and approach, and therefore the different equation could be the reason when comparing with the most common energy equations (Schlich, Schumm et al. 2010, Schlich 2014).

Another problem in the calculation of the energy expenditure is the accuracy in the older population. Most equations are based on really young study samples and do not consider changes related to ageing (Harris and Benedict 1919, Schofield 1984). The youngest subjects recruited for the study of Harris and Benedict for example, were 15 years old. They could clearly be defined as adolescents (Harris and Benedict 1919). The study and following equation by Müller et al. was the first one which separated kids, adolescents and adults into three different groups resulting in the establishment of three different equations (Müller, Bosy-Westphal et al. 2004).

When comparing all different energy equations with the reported energy intake of the subgroups divided by age (Table 5) it can be seen that all equations predict a higher energy expenditure for the older subjects even though the energy intake is not significantly different ($p=0.81$) to the younger women (Figure 6). While Owen is the most accurate for the younger subgroup, the AMI is more adequate for the older one.

The division of the study sample by age and size into eight subgroups even enlarges the gap between the predictive energy equations and the actual energy intake. An average women over 30 years of age, wearing size extra-large has an estimated energy expenditure of around 3000 kcal/day when using the most frequently energy equations by Harris-Benedict and Schofield, which is more than 1000 kcal higher than the diary based energy intake of around 1900 kcal (Table 7). Again the AMI is the only one predicting an energy expenditure near the actual intake, what acknowledges the previous assumptions that it's especially accurate for the groups including women who are older or wearing sizes large and extra-large.

The physical activity behaviour of the study population was measured by using the MET values of the 'Compendium of Physical Activities' (Ainsworth, Haskell et al. 1993, Ainsworth, Haskell et al. 2011). For every subject an individual and detailed evaluation was done. However, the physical activity can basically divided into four main groups which are defined as: sedentary activity (< 1.5 MET/h), like sleeping or watching TV; light activity ($1.5 - 3$ MET/h), like deskbound activities; moderate activity ($3 - 6$ MET/h), like walking or Yoga; and vigorous activity (> 6 MET/h), like jogging or cycling (Hamer, Kivimaki et al. 2012, Elliott, Baxter et al. 2014). The mean of the whole study population and of the different subgroups show that the average study population maintains a daily lifestyle with a light activity. According to the WHO guidelines adults should perform at least 150 min of moderate-intensity physical activity during the week (Organization 2010). Since the physical activity was only measured as a total for the day, it cannot be really differentiated, if the WHO recommendation was achieved. However, a study population with an average MET/h of 1.65 can be defined as at least moderate active, which also reflects the average physical activity in German-speaking countries (James, Troped et al. 2013, Wallmann-Sperlich and Froboese 2014, Gerovasili, Agaku et al. 2015).

Unexpectedly the physical activity behaviour was better in the older than the younger group, despite their average higher weight. The reason therefore could be the higher percentage of nurses, especially in the older group, who have a more physical exhausting work day than students, which mainly participated in the younger group. Furthermore, the physical activity

increases, when a person has a fixed date and a routine for the physical workout (Raymore, Barber et al. 2001, Hamer, Kivimaki et al. 2012). Most younger subjects were students without an every-day-routine, while the older subjects had at least a part-time job. Therefore they had their whole week planned including their physical workout. However, the chosen cut-off for the two groups was 30 years. So especially women aged between 30 and 45 years were still very active and raised therefore the result of the whole group. Consequently the results shouldn't be used as a representation for the female elderly population, since therefore a higher cut-off of the age would have been necessary.

Conclusion

Comparing all eight energy equations, no equation was found which is the most adequate for all different clothes sizes and ages.

While all energy equations are still quite accurate for the younger and lean women, the overestimation of every equation increases with weight and age. The only exception is the AMI, which is the most adequate for the women wearing large or extra-large, but also the only one significantly different ($p < 0.05$) to the energy intake in young women wearing size small. In the S- and M-groups Owen is the most accurate, followed by Livingston, Müller and Mifflin-St. Jeor. While Owen is still acceptable in the L-group the other three overestimate the energy intake by at least 23%. The energy equations by Harris-Benedict and Schofield, which are still used most frequently are also the ones overestimating the energy expenditure the most, with sometimes more than 60%. The Oxford equation builds the gap with an average overestimation of 28%, which is not as high as Harris-Benedict or Schofield, but also not as adequate as Owen, Livingston, Müller, Mifflin-St. Jeor or the AMI.

5) Abstract

Background: Over the last years food habits and lifestyle activities of the population have changed globally. Weight is increasing while physical activity is decreasing, which strengthens the need for weight reduction. Programs today are still based on energy equations developed during the last century. Recent studies, however, showed that energy equations tend to overestimate the actual energy intake. Here we compared the most common equations with recently developed ones and the actual energy intake. The energy equations considered were: Harris-Benedict, Schofield, Owen, Mifflin-St. Jeor, Müller, Livingston, Oxford and the AMI.

Methods and subjects: 102 women, between 18 and 65 years, were recruited in Austria, Germany and Switzerland. Over the period of one month they had to complete a dietary record during the first and the last week of participation, where they considered all of the daily consumed food, their physical activity behaviour and their morning weight. Furthermore weight, height and the circumferences of hip, waist and neck were measured before and after the study month. The means of the actual energy intake (kcal per day) and the physical activity (MET per hour) were calculated and compared with the eight mentioned energy equations.

Results: There was no significant weight change after the study month but a significant difference between the calculated energy requirement and the real energy intake. The whole study sample was divided into four subgroups due to their clothes sizes (S, M, L and XL). While there was no significant difference of the diary based energy intake between the subgroups, all energy equations recommended 600 to 800 kcal/d more for a women wearing size XL compared to one wearing S. The only exception was the AMI which recommended almost the same in every group. Moreover the group wearing XL was the most active one (1.74 ± 0.31 MET/h).

Conclusion: The results show that all energy equations tend to overestimate the actual energy intake. The most frequently used energy equations of Harris-Benedict and Schofield overestimated the most, with 30% and sometimes even 60% in the overweight groups. The most adequate equations were the one by Owen and the AMI. For lean women Owen is very accurate with an overestimation of only 6%, for the L- and XL-groups the AMI was most accurate.

6) Zusammenfassung

In den letzten Jahren haben sich Essgewohnheiten und die sportliche Aktivität der Bevölkerung drastisch verändert. Während immer mehr Kalorien aufgenommen werden, wird sich gleichzeitig immer weniger bewegt, was zu einer ständigen Zunahme des Gewichts führt. Dadurch suchen immer mehr Übergewichtige und Adipöse Hilfe bei Programmen die versprechen ihr Gewicht zu senken. Oftmals jedoch ohne Erfolg. Dies könnte daran liegen, dass viele formelbasierten Ernährungsempfehlungen während des letzten Jahrhunderts entwickelt wurden. Daher sollen in dieser Studie diese Formeln mit der tatsächlichen Energieaufnahme verglichen werden. Die dafür berücksichtigten Formeln waren Harris und Benedict, Schofield, Owen, Mifflin und St. Jeor, Müller, Livingston, Oxford und der AMI.

Dafür wurden 102 Frauen, im Alter von 18 bis 65 Jahren, in Österreich, Deutschland und der Schweiz rekrutiert. Innerhalb eines Monats mussten sie während der ersten und der letzten Woche ein Tagebuch ausfüllen, wo alle konsumierten Lebensmittel, die tägliche körperliche Aktivität und das Gewicht jedes Morgens notiert wurden. Während eines Einführungs- und eines Abschlusstermins, wurden außerdem Größe, Gewicht und die Umfänge von Hüfte, Taille und Hals gemessen. Durch diese Angaben konnte der Leistungsumsatz (kcal pro Tag) mit den verschiedenen Formeln berechnet und später mit der tatsächlichen Energieaufnahme (kcal pro Tag) verglichen werden.

Es konnte während des Monats keine signifikante Gewichtsveränderung, aber ein signifikanter Unterschied zwischen den berechneten Energieempfehlungen und der tatsächlichen Energieaufnahme festgestellt werden. Die Studienpopulation wurde außerdem anhand ihrer Konfektionsgröße in vier Untergruppen unterteilt (S, M, L und XL). Während es keinen signifikanten Unterschied in der tatsächlichen Kalorienaufnahme gab, stieg die empfohlene Energieaufnahme um bis zu 800 kcal pro Tag von der S- zu der XL-Gruppen. Eine Ausnahme bildete hier der AMI, welcher in jeder Gruppe fast die gleiche Kalorienaufnahme empfahl. Die XL-Gruppe war außerdem die körperlich aktivste ($1,74 \pm 0,31$ MET pro Stunde).

Anhand der Ergebnisse konnte man sehen, dass alle formelbasierten Energieempfehlungen die tatsächliche Energieaufnahme überschätzen. Die Formeln von Harris-Benedict und Schofield, welche die meist genutzten sind, waren gleichzeitig auch die Formeln welche die Kalorienaufnahme am meisten überschätzten. Für normalgewichtige Frauen war die Formel von Owen am genauesten und für Frauen mit den Konfektionsgrößen L und XL der AMI.

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Curriculum Vitae Therese Schwalenberg

Education and Training

- Since 11/2012 Masters studies in nutritional sciences, **University Vienna (Austria)**
Main focus: Public Health
Master thesis: *The comparison of different energy equations with the actual energy intake*
- 10/2008 – 11/2012 Bachelors studies in nutritional sciences, **University Vienna (Austria)**
Subjects included: Natural scientific basics; human diet and nutrition; biometrics, statistics and data processing; specific dietetics
Bachelor thesis: *Type 1 Diabetes mellitus and the effect of vitamin D as a prevention and a therapeutic measure*
Graduation: 09.11.2012, fulfilment of the requirements for the degree of Bachelor of Science (BSc)
- 08/1999 – 05/2008 **Gymnasium Petrinum Brilon (Germany)**
Main subjects: English, Biology, Mathematics and Education science
Graduation: 30.05.2008

Work Experience

- 02/ 2013 till present **Masterthesis, Department of Nutritional Sciences, University Vienna (Austria)**
Study on the actual energy intake of women and comparison with eight energy equations
- 06/2013 – 09/2014 **Environment Education Austria, Green Island, Vienna (Austria)**
Workshopleader
Developing and managing the workshop “You are what you eat” for kids

Internships

11/2013	Nutrition Day, General Hospital Vienna (Austria) Collecting nutrition-related data of the patients
09/2013	Publisher Hanreich, Vienna (Austria) nutrition-related research and summary of different topics, conception and design of articles and newsletter, answering, response of consumer questions, managing marketing strategies
07/2011 - 08/2011	AWO Center of Health-Care, Calbe (Germany) Expert advice about diets and nutrition, schooling about Diabetes mellitus
07/2009	Hospital Maria-Hilf, Brilon (Germany) preparation of dishes, nutrition-related consultations, design of diet protocols, schooling about diabetes

Language skills

German (native), English (fluent), Swedish (intermediate), French (basic)

PC skills

MS Office, SPSS, nut.s, Adobe Photoshop & Illustrator

Related other experience

08/2014	German Institute of Human Nutrition, Potsdam-Rehbrücke (Germany) <i>Summer School in Nutritional Epidemiology</i>
01/2014 – 06/2014	Erasmus: University Uppsala, Sweden
03/2006 – 04/2006	German-American-Partnership-Program: Oak Grove High School, San Jose, California