Example of a protocol for identification of misreporting (under- and over-reporting of energy intake) based on the PILOT-PANEU project[1]

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[1] The content of this Appendix is used with permission of the PILOT-PANEU project (Ambrus et al., 2013).

OBJECTIVES

The exposure assessment which is crucial in risk assessment needs reliable and accurate data for food consumption (Codex Alimentarius Commission, 2003). A variety of valid dietary methods is currently applied and each method that is appropriate for use in large surveys may be biased due to a different impact of inadequate reporting of food consumption. The identification of misreports of foods consumed (including under-reporters and over-reporters) is an important aspect in the assessment of uncertainties in food consumption data. Still, there are no methods and criteria for evaluation of misreporting of foods consumed that are widely accepted as the best choice for different age/sex groups in dietary surveys resulting in difficulties to compare the data directly between countries.

This protocol includes a harmonized approach and unified criteria to identify dietary misreporting in the framework of the Pan-European food consumption survey 'EU Menu' based on critical literature review with respect to methods for identifying under-reporters and over-reporters of dietary intakes in nationally representative samples of adolescents, adults and elderly people aged 10-74 years in Europe.

1. Definitions

Reported Energy Intake (EIrep) EIrep is the average daily energy intake evaluated on the basis of foods consumed for two non-consecutive days estimated by 24 h dietary recall.

Estimated BMR (BMRest) is Basal Metabolic Rate assessed from the Schofield equations (Schofield, 1985) using person's weight (kg) and height (m).

Physical Activity Level (**PAL**) is the mean PAL value assigned to low, moderate and high level of physical activity by age as defined from EFSA Panel on Dietetic Products, Nutrition and Allergies in the scientific opinion on DRV for energy (EFSA, 2013).

Cut-offs (confidence limits) determine whether the mean reported energy intake is plausible as a valid measure of food intake even if chance has produced a dataset with a high proportion of days of genuinely low (or high) intake (Black, 2000a).

Plausible reporters are subjects with estimated values of the ratio EIrep:BMRest ranging between calculated lower cut-off and upper cut-off values that are specific for the population under study allocated to the different category of physical activity.

Misreporters of energy intake are either under- or over-reporters of energy intake. For under- and over-reporters, see below.

Under-reporters are subjects with estimated values of EIrep:BMRest below the calculated lower cut-off value specific for the population under study allocated to the different category of physical activity.

Over-reporters are subjects with estimated values of EIrep:BMRest above the upper calculated cut-off value specific for the population under study allocated to the different category of physical activity.

2. Background information

The assessment of dietary intake based on data reported/recorded by the study participants is often prone to errors. One of the main sources of error is misreporting, comprising both under- and over-reporting. The magnitude of misreporting of foods consumed may lead to biased estimations of dietary exposure.

Many studies evaluate the magnitude of under-reporting, determinants of under-reporting and characteristics of under-reporters, but less emphasis has been given to studying over-reporting. Although the prevalence of over-reporting has been reported of being much lower compared to under-reporting, solely concentrating on under-reporting might lead to only partially addressing the bias in food consumption estimates (Livingstone et al., 2004; Trolle et al., 2011a).

Reported food consumption may be affected by the participants' personal characteristics**,** including Body Mass Index, age, sex, educational level, health consciousness, dieting, degree of obesity (Moffatt and Owens, 1991; Tooze et al., 2004; Maurer et al., 2006). Obese subjects are more prone to under-reporting than over-weight or normal-weight participants (Martin et al., 1996). Under-reporting is observed to be more frequent in females than in males and in elderly subjects than in younger adults (de Vries et al., 1994; Johnson et al., 1994; Hirvonen et al., 1997). Under-reporting also varies among food categories with a tendency to under-report foods high in fat or sugar (Cook et al., 2000; Mirmiran et al., 2006). Under-reporting could also have a geographical dimension (Harrison et al., 2000). Over-reporting, on the other hand, is more common in the younger than in the older age groups (Johnson et al., 1998; Conway et al., 2003; Subar et al., 2003).

The magnitude, nature and determinants of misreporting by using different dietary methods are analyzed in numerous publications and they reveal their specific limitations. Livingstone and Black (Livingstone and Black, 2003) on the basis of 47 studies have estimated that there are no significant differences between the validity of most dietary methods – weighed and estimated records, single or multiple 24-h dietary recall (24HDR), diet history. In a more recent review (Tooze et al., 2004; Poslusna et al., 2009) the extent of misreporting by adults was analyzed on the basis of the results from 37 relevant dietary assessment studies carried out with 24HDR, estimated and weighed food records. It was found that the magnitude of under-reporting of energy intake is similar by using each of the three dietary assessment methods (about 30%). Despite the presumption that the magnitude of misreporting is the lowest in studies using weighed food records, the analyses of the available data have not supported this.

Validation studies of energy intake data have led to the widespread recognition that much of dietary data of children and adolescents is prone to misreporting, mainly underreporting (Livingstone et al., 2004). Currently there are not clear evidences which dietary assessment method provides more accurate data for children. One of the recent reviews (Burrows et al., 2010) including 15 cross-sectional dietary studies on children and adolescents published between 1973 and 2009 compares misreporting magnitude of energy intake estimated by the most used dietary methods with the gold standard measure, doubly labelled water (DLW). The authors conclude that the 24-HDR method is superior to the record method in the age group of 4–11 years and the diet history method provides better estimation for adolescents aged ≥ 16 years. Andersen et al. 2011 (Andersen et al., 2011) recommend repeated 24-HDR as trans-European dietary assessment method for schoolchildren. However, in all publications on dietary misreporting among children and adolescents the authors express an opinion that more research on validity of dietary methods is needed.

Energy intake (EI) is the foundation of the diet, because all other nutrients must be provided within the quantity of food needed to fulfil the energy requirement. Thus if total EI is underestimated, it is probable that the intakes of other nutrients are also underestimated (Livingstone and Black, 2003). Currently the most common approach to evaluate misreporting of food consumption is to assess the adequacy of reported energy intake. The validation of reported energy intake (EIrep) rests on the fundamental equation:

Energy intake (EI) = Energy expenditure (EE) with the assumption that at the group level changes in body stores can be ignored (Goldberg et al., 1991; Black, 2000a).

The three methods that are used to estimate the plausibility of reported energy intake rest on these main principles**:** 1. comparison of self-reported EI with EI required maintaining weight; 2. direct comparison of reported EI and measured or estimated EE; 3. comparison of reported EI with presumed energy requirements, both expressed as multiples of basal metabolic rate (Livingstone and Black, 2003).

Direct comparison of EI with measured EE is considered as the most reliable technique to evaluate EI misreporting but this method has also some limitations (Martin et al., 1996; Livingstone and Black, 2003; Tooze et al., 2004; Poslusna et al., 2009). The "gold standard" for measuring EE is the Doubly Labelled Water (DLW) technique (Goldberg et al., 1991; Livingstone and Black, 2003; Mirmiran et al., 2006). Although DLW technique provides an objective measure of EE, it is expensive and cannot be used as a routine tool for large surveys. Reported EI can also be compared directly with estimated

EE derived from heart rate monitors, accelerometers, physical activity diaries and questionnaires (Black and Cole, 2001; McCrory et al., 2002; Livingstone et al., 2003; Ramirez-Zea, 2005; Dollman et al., 2007; Rennie et al., 2007). The precision and validity of these methods is certainly poorer and the sensitivity and specificity for detecting invalid reporters are worse than when DLW is used (Livingstone and Black, 2003).

Currently the most used method for assessment of misreporting of EI is the evaluation of EIrep against presumed energy requirements. In this technique EIrep is expressed as a multiple of the mean BMR estimated (BMRest) from equations, and it is compared with the presumed mean EE of the studied population, which is also expressed as multiple of the BMR. The ratio of EIrep and BMRest (EIrep:BMRest) is referred to as the physical activity level **(PAL)** (Black et al., 1991; Black, 2000a; Livingstone and Black, 2003). This method was first developed by Goldberg and co-workers, 1991 (Goldberg et al., 1991) and it is one of the most widely used procedures for identifying inaccurate reports of energy intake. It takes into account the errors associated with the number of subjects, the length of the dietary assessment and variation in each of food intake, BMR and physical activity. More recently, the principles of the method of Goldberg, Black et al. have been re-considered and the factors to be used in the equations have been revised by Black (Black, 2000a; 2000b). The Goldberg cut-off technique is applied for evaluation of reported energy intakes at group and individual level. Black reports that the sensitivity of the Goldberg cut-offs is improved when subjects are assigned to low, moderate and high activity levels, and different Physical Activity Levels (PALs) and cut-off values are applied to each level without loss of specificity (Black, 2000b). This information is often acquired from physical activity questionnaires. When such questionnaires are used in large-scale studies, they are required to be simple, easy to administer and analyze.

BMR for calculation of the Goldberg cut-offs can be either measured or estimated from predictive equations. Some studies measure a classical BMR using indirect calorimetry (Klesges et al., 1995; McKenzie et al., 2002). Alternatively, BMR can be predicted from age- and sex-specific equations as those derived by Schofield or Henry (Schofield, 1985; Henry, 2005). Schofield equations are the most frequently used in the dietary studies. They formed the basis for the equations derived and used by FAO/WHO/UNU (FAO/WHO/UNU, 1985; 2004). After the analysis of the various publications on the numerous newly developed equations to improve predictive power of Schofield equations, the experts of EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA) concluded (EFSA NDA Panel, 2013) that Schofield equations can be considered as equally valid as those of more recent equations including those of Henry (Henry, 2005). For children and adolescents, several equations based on age, body mass, height and sex are available to predict BMR. Both the Schofield and the Henry equations have been derived from large datasets covering the age groups from 0 to 18 years unlike the other equations.

Assessment of dietary misreporting depends on the choice of PAL for different categories of physical activity. PAL can be estimated either from time-allocated lists of daily activities or by using DLW technique as well as heart rate monitoring. Energy expenditure for growth of children and adolescents was accounted mainly by slightly increasing of PAL. Through applying the different methodological approaches variety of PAL values have been estimated for the different categories of physical activity for adults and adolescents. Some authors also determine average PAL values for defined populations under study.

In FAO/WHO/UNU report (1985) on energy and protein requirements (FAO/WHO/UNU, 1985) PAL values were established for low, moderate and high physical activity for adult men as 1.55, 1.78 and 2.10 and for women as 1.56; 1.64 and 1.82, respectively. For adolescents the average PAL values have been established by age and sex. The values are getting lower with the increasing of the age: boys / girls aged 10 years - PAL 1.76 / 1.65; boys/ girls of age 17 years – PAL 1.6 /1.52. In 2004 FAO/WHO/UNU (FAO/WHO/UNU, 2004) have established PAL values for children and adolescents for 3 different categories of physical activity lifestyle specified by age and sex, for example for boys / girls aged 15 years PAL for light activity is 1.6/1.5, for moderate activity- 1.85/1.75, and for vigorous activity – 2.15/ 2.00. For adults the FAO/WHO/UNU Council in 2004 determined PAL ranges associated with a population's lifestyle classified as light (PAL 1.40-1.69), moderate (PAL 1.70-1.99) and vigorous (PAL 2.00-2.40). The Council concluded that for older adults and elderly people the same PAL values should be implemented.

The USA Institute of Medicine (IoM) derived through the DLW technique four PAL categories concerning all age groups over 3 years of age for both sexes: sedentary (1.0-1.39, mean 1.25); low active (1.4-1.59, mean 1.5), active (1.6-1.89, mean 1.75), very active (1.9-2.49, mean 2.2) (Institute of Medicine, 2005). The PAL coefficients which IoM applied for estimation of energy requirements however are very low: 1.00 (for sedentary men and women), 1.11 (for low active men), 1.12 (for low active women), 1.25 (for active men), 1.27 (for active women), 1.48 (for very active men), and 1.45 (for very active women).

On the basis of combined dataset of DLW studies, the Scientific Advisory Committee on Nutrition (SACN) in UK has determined PAL values of 1.49, 1.63 and 1.78 for adults and 1.66, 1.73 and 1.85 for adolescents of age 10-18 years equated to the 25^{th}, median and 75^{th} centile of PAL distribution (SACN, 2011). These values have been equated to the general physical activity categories: sedentary, low and moderate activity. Currently, there is no evidence of any significant variation of PAL with either body mass or sex, the age explained <1% of the variance in PAL among adults (SACN, 2011). On this basis SACN has adopted the same values of PAL for both genders and PAL estimated for adults to be applied to older adults whilst general health and mobility are maintained.

EFSA NDA Panel in the scientific opinion on Dietary Reference Values (DRV) for energy (EFSA, 2013) after re-analyses of designated PAL values from the national/ international authorities, considering large dataset from the current published data has adopted PAL values for adults of 1.4, 1.6, 1.8, 2.0 and >2.0 that can indicate low active (sedentary), moderately active, active, very active and highly active lifestyle, respectively (EFSA, 2013). From the observed PAL values in adolescents 10-18 years old the Panel has chosen 1.6, 1.8 and 2.0 to be assigned for low, moderate and vigorous physical activity, respectively as these coefficients include addition by 1% for energy expenditure for growth. The determined PAL values from the EFSA NDA Panel are based on large dataset, reflect the current knowledge on the subject and are convenient to be used in large nutrition surveys for the purposes of dietary misreporting assessment.

For evaluation of dietary misreporting by cut-off methodology of Goldberg, the defined PAL values have been used by the authorities in most of the studies, in other studies PAL values have been established for the investigated population.

To derive cut-offs for evaluation of under-reporting and over-reporting of energy intakes a number of factors need to be considered. These include the within-subject day-to-day variation in energy intake; the number of days of dietary assessment (more days reduces the day-to-day variation); the number of subjects in the sample population (more subjects improves the precision of the measurement); the variation in repeated measurement of BMR or the precision of estimated *versus* measured BMR; the between-subject variability in PAL (Goldberg and Black, 1998; Black, 2000a). The equation of Goldberg (Goldberg et al., 1991) revised by Black (Black, 2000a) to establish cut-offs for assessment of dietary misreporting takes all these variables into account.

The value of 12.5% for between-subject variation in physical activity used in the original paper of Goldberg et al. (Goldberg et al., 1991) was determined by FAO/WHO/UNU (1985) but only one study was cited to support this value. Accumulated data from DLW studies revealed a wide range of PAL. On the basis of large dataset derived by applying of DLW method, Black (Black, 2000a) suggested 15% as suitable average value to substitute into Goldberg equation.

Data on within-subject daily variation in energy intake show enormous variability from day to day (10-50%) (Tooze et al., 2004; Poslusna et al., 2009). Review and analyses of data from a few large and reliable dietary studies by Black resulted in a pooled mean of 23% of within-subject variation and she proposed 23% as suitable average value to be used into Goldberg equation (Black, 2000a).

Since energy requirement and intake are expressed as multiples of the BMR, taking also into account the between-subject variation, only within-subject variation need to be considered in calculating the confidence limits (Black, 2000a). Variation in BMR depends on the methods used for its evaluation. Within-subject variation in BMR obtained from DLW studies was assessed by Black to be average of

4%. Where measured BMR is missing, it may be calculated from weight and height or weight alone. The most used equations of Schofield for estimation of BMR have been used by Goldberg et al. (Goldberg et al., 1991) in their cut-off technique for evaluation of under- and over-reporting and coefficient of 8% for the within-subject variation in BMR was applied. Black (Black, 2000a) re-estimated this coefficient considering the available specific values for the different age - sex groups of the Schofield equations and suggested 8.5% as suitable average value to substitute into Goldberg equation.

Many researchers have used the suggested by Black standard coefficients for between-subject variation in PAL, within-subject energy intakes and BMR (Ferrari et al., 2002; Lioret et al., 2011; Trolle et al., 2011b) but in some studies specific for the sample population coefficients for variation in within-subject energy intakes have been calculated (Livingstone et al., 2003; Rennie et al., 2007).

3. Recommendations

- Equations developed by Schofield et al. (1985) or Henry (2005) should be applied for the calculation of estimated basal metabolic rate (BMR_{est}) using height and weight information, when available. Assessment of the average ratio of energy intake to BMR_{est} ($EI:BMR_{est}$) should be performed by age and gender stratum.
- The assessment of the prevalence of under-reporting and over-reporting of dietary intakes should be performed both at group level and at individual level using the Goldberg cut-off method (Goldberg et al., 1991), updated by Black (2000a). The evaluation should be carried out at the whole survey level, separately for both genders at the survey level, and separately for both genders in all age classes of the sample.
- The physical activity level (PAL) to be applied, as recommended by the Goldberg cut-off method (Black, 2000a), is based on different categories of physical activity (low, moderate and vigorous physical activity). The age-specific PAL values for the three different categories of physical activity adopted by the EFSA NDA Panel in the scientific opinion on Dietary Reference Values (DRV) for energy (EFSA NDA Panel, 2013) should be used. If no indication of the specific physical activity categories are available, the following indicative PAL values may be assigned to represent average physical activity. For children of 1-3 years, a PAL value of 1.4 may be used; for children, aged 4-9 years a PAL value of 1.6 may be used and for adolescents aged 10-17 years a PAL value of 1.8 may be used, if no measured information on PAL is available. For adults of 18-69 years, a PAL value of 1.6 may be used. For elderly people, aged 70 to 74 years, a PAL value of 1.4 or 1.6, equating to low/moderate physical activity of adults, should be applied depending on the national habitual physical activity of older adults (Ambrus et al., 2013; EFSA NDA Panel, 2013).
- If PAL values, measured using monitoring devices (e.g. accelerometers), or valid estimates of the PAL are available, they may be used as supplementary information to assign more accurate physical activity categories.
- **The overall group-level evaluation includes the following steps:**
  - the appropriate PAL values (low, moderate or vigorous activity) for the individuals are assigned;
  - individual values of reported EI (EI_{rep}):BMR_{est} are calculated;
  - the mean $EI_{rep}:BMR_{est}$ is calculated for each defined group by category of PAL for the age
  - specific cut-offs are calculated for each defined group by activity category for the age applying the corresponding PAL values and considering the number of included subjects in the group (e.g. n = 30).

- the mean $EI_{rep}:BMR_{est}$ of each group is compared with the calculated specific cut-offs for this group.

- **The individual-level evaluation includes the following steps:**
  - The appropriate PAL value (low, moderate or vigorous activity) for the individuals are assigned;
  - Individual values of $EI_{rep}:BMR_{est}$ are calculated;
  - Cut-offs for each physical activity category by age are calculated using n = 1. Adopted PAL values for each category of activities by age are applied;
  - The individual $EI_{rep}:BMR_{est}$ of each subject assigned to the activity categories is compared with the calculated lower and upper cut-offs for the corresponding activity category.

- Exclusion of under- or over-reporters from the datasets introduces unknown bias; therefore, the identified under- and over-reporters should not be excluded from the sample but should be identified and reported.

4. Practical recommendations for evaluation of under-reporting and over-reporting of energy intakes

4.1. The principles of the Goldberg cut-off method

The principles of the Goldberg cut-off method and the statistical derivation of the equations to calculate them were described originally by Goldberg et al (Goldberg et al., 1991). More recently, the equations have been restated and the factors to be used are revised by Black (Black, 2000a).

Goldberg cut-off method is based on the basic premise: if weight is stable then energy expenditure (EE) equals energy intake (EI). Both EIrep and presumed EE can be expressed as multiples of BMR. For evaluation whether EIrep is a plausible measure of the actual intake during the period of investigation it is necessary to estimate the confidence limits of the agreement between EI:BMR and PAL. Statistically if mean reported EI:BMR is less than the lower 95% confidence limit or lower cut-off then it has low probability (<2.5%) that the EIrep could represent genuinely low intakes obtained by chance. Similarly, if reported mean EI:BMR is greater than the upper 95% confidence limit or upper cut-off then it has low probability (<2.5%) that the reported intake could represent genuinely high intakes obtained by chance (Goldberg and Black, 1998)(40). The sensitivity of the Goldberg cut-off method is improved due to suggestion of Balck: the studied subjects to be assigned to low, medium and high activity levels, and different PAL and cut-off values to be applied to each activity level (Goldberg et al., 1991; Goldberg and Black, 1998; Black, 2000a). The revised Goldberg cut-offs to evaluate reported energy intake can be used for evaluation the group mean EIrep as well as to evaluate EIrep at the individual level.

For implementation of the cut-off technique of Goldberg & Black to evaluate misreporting of EI the following data are needed:

- Information on age and gender of the studied subjects;
- Individual data for EI for both studied days obtained by 24-H dietary recall;
- Measured values of weight and height of the subjects;
- Data for physical activity of each subject aged 15-69 years derived by short version of the International Physical Activity Questionnaire (IPAQ).

4.2. Estimation of cut-off values for under-reporting and over-reporting of energy intakes of the study population

According to Black (Black, 2000a) the following equations should be applied to derive cut-offs for evaluation of misreporting of EI of the studied population:

$$EIrep{:}\,BMRest > PAL \times \exp\left[SDmin\ \times \frac{S/100}{\sqrt{n}}\right]$$

and

$$EIrep{:}\,BMRest < PAL \times \exp\left[SDmax\ \times \frac{S/100}{\sqrt{n}}\right]$$

The first and second equations are used to calculate the specific lower cut-off and upper cut-off values for defined population group to identify under- and over-reporters.

In the equations:

SDmin is -2 for the 95% lower confidence limit,

SDmax is +2 for the 95% upper confidence limit,

n is the number of subjects included in each defined group.

Reported Energy Intake **(EIrep)** should be calculated as average value on the basis of energy intakes estimated for each of non-consecutive days applying 24-h dietary recall.

Estimation of BMR **(BMRest)** of each studied individual should be performed applying the equations of Schofield. The equations require information on the person's gender, age, weight and height. The information on the person's height increases the accuracy of the estimations. If the height cannot be measured equations including only weight can be used.

Schofield equations for estimating BMR (kcal/d) from weight (kg) and height (m)

Gender/ Age (years)	**BMR (kcal/d)**
Males	
10-17	16.2 x Wt + 137 x Ht + 516
18-29	15.0 x Wt – 10 x Ht+ 706
30-59	11.5 x Wt – 2.6 x Ht+ 877
60+	9.1 x Wt + 972 x Ht- 834
Females	
10-17	8.4 x Wt + 466 x Ht + 200
18-29	13.6 x Wt +283 x Ht+ 98
30-59	8.1 x Wt +1.4 x Ht+ 844
60+	7.9 x Wt +458 x Ht+ 17.7

When the measurement of height is not possible the following equations of Schofield for estimating the BMR of adolescents, adults and elderly could alternatively be used:

Schofield equations for estimating BMR (kcal/d) from weight (kg)

Gender/ Age (years)	BMR (kcal/d)
Males	
10-17	17.7 x Wt + 658.2
18-29	15.0 x Wt + 692.1
30-59	11.5 x Wt + 873.0
60+	11.7 x Wt + 587.7
Females	
10-17	13.4 x Wt + 692.6
18-29	14.8 x Wt + 486.6
30-59	8.1 x Wt +845.6
60+	9.1 x Wt + 658.4

Similarly, equations for estimating BMR based on weight only or both weight and height have been published by Henry (2005).

Age specific **PAL** values for low, moderate and active (vigorous) physical activity adopted by EFSA NDA Panel in the scientific opinion on DRV for energy (2013) should be applied in the equations to establish misreporting of EI for individuals of age 15- 69 years.

Age (years)	**Mean Physical Activity Level (PAL) for adolescents and adults of age 15-69 years**		
	Low	**Moderate**	**Vigorous**
15-17	1.6	1.8	2.0
18-69	1.4	1.6	1.8

- **For adolescents of 10-14 years** the PAL value of 1.8 adopted by EFSA NDA Panel for moderate physical activity for this age group should be used.
- **For elderly people aged 70-74 years** the PAL value of 1.4 or 1.6 should be applied for low/ moderate physical activity of adults. The choice of PAL value should consider the national habitual physical activity of elderly adults (aged 65-69 years) estimated by IPAQ. The proposal to use PAL value for adults is based on the current data that show small decreasing in PAL for adults related to age (<1%) and the common approach to apply the same PAL values for elderly people whilst general health and mobility are maintained.

In the equation of Goldberg/ Black **S** is the factor that takes account of the variation in energy intake, BMR and PAL.

S is given by the equation:

$$S = \sqrt{\frac{CV^2{}_{wEI}}{d} + CV^2{}_{wB} + CV^2{}_{tP}}$$

Where:

CV_{wEI} is the within-subject variation in energy intake,

d is the number of days of diet assessment (in our study it is 2),

CV_{wB} is the within-subject variation in repeated BMR measurements or the precision of estimated BMRest compared with measured BMR. This includes both measurement error and variation with time on repeated BMR measurements.

CV_{tP} is the total (between-subject) variation in PAL, but this figure includes also within-subject variation and methodological errors (Black, 2000a).

The revised factors by Black (3) should be applied:

CV_{wEI} = 23%;

CV_{wB} = 8.5%;

CV_{tP}=15%.

CV_{tP}=15%.

Using the revised factors of Black, the calculated value of S factor for 2 days studied food consumption (d=2) is the following:

$$S = \sqrt{\frac{CV^2{}_{wEI}}{d} + CV^2{}_{wB} + CV^2{}_{tP}}$$

$$S = \sqrt{\frac{23^2}{2} + 8.5^2 + 15^2} = \sqrt{264.5 + 72.25 + 225} = \sqrt{561.75} = \mathbf{23.7}$$

The coefficient of variation of within-subject energy intakes of the sample population under study can be calculated according to the formula presented by Black (Black, 2000a):

$$\text{Pooled mean } \mathrm{CV_w} = \sqrt{\sum_{i=1}^{n} (\mathrm{CV_i^2}) \ / \ n}$$

Where:

CVi is the CV calculated for each subject from the number of days of dietary assessment available for that subject,

n is the number of subjects.

4.3 Using the Goldberg cut-offs to evaluate reported energy intakes

There are two strategies that can be applied to evaluate reported energy intakes: at group and at individual level.

Evaluation of EIrep at group level

The procedure is the following:

- The individuals who are investigated for physical activity by IPAQ (aged 15-69 years) are assigned to low, moderate or vigorous activity categories on the basis of data obtained. Subjects in the age groups of 10-14 and 70-74 are assigned to the physical activity levels as described above (children to moderate activity, elderly people to low or moderate activity);
- Individual values of EIrep:BMRest are calculated;
- The mean EIrep:BMRest is calculated for each defined group by category of physical activity for the age;

- Specific cut-offs are calculated for each defined group by activity category for the age applying the corresponding PAL values and considering the number of included subjects in the group;
- The mean EIrep:BMRest of each group is compared with the calculated specific for this group cut-offs.

If the mean EIrep:BMRest for the studied group is lower than the estimated lower cut-off, it means that the majority of the individuals included in the group have under-reported their energy intake. Misreporting is detected more correctly in large studies since the interval between lower and upper cut-offs become substantially narrow as the number of studied people (n) increases (Black, 2000a). According to Black (Black, 2000a) the mean EIrep:BMRest of groups with n>100 may be compared directly with the used PAL because the changing in the number of subjects over 100 has small effect on the confidence limits (cut-offs). The applying of suitable PAL values for studied age groups assigned to three activity levels improves the sensitivity of the Goldberg cut-off method and results in more adequate evaluation of misreporting comparing with the approach to use a single PAL.

The evaluation of misreporting of energy intake at group level can be used to determine the overall bias to reported energy intake, to provide information whether the defined studied group as total has plausible or inadequate reported dietary intake but cannot identify the rate of under- and over-reporters.

Evaluation of EIrep at individual level

It is important to note that when we evaluate reported energy intakes at individual level we have to use n=1 in calculating the cut-offs.

The procedure of the evaluation of misreporting of studied persons is the following:

- Individual EIrep:BMRest is calculated;
- Physical activity of each subject aged of 15-69 years is investigated by IPAQ and on the basis of data obtained the individual is classify into low, moderate or vigorous activity. For the subjects aged of 10-14 and 70-74 years appropriate single PAL values are applied as it is described above;
- Cut-offs for each physical activity category by age for n=1 are calculated. Adopted PAL values for each category of activities by age are applied;
- The individual EIrep:BMRest of each subject assigned to some of the three activity categories is compared with the calculated lower and upper cut-offs for the corresponding activity category.

The strategy for evaluation of misreporting at individual level provides possibilities to determine the rate of under-reporters, and plausible over-reporters; to investigate specific characteristics of the under- and over-reporters, risk factors related to misreporting, etc. Confidence limits (cut-offs) are substantially wider when n=1 compared with larger and on this reason the ability of the Goldberg cut-off method to identify invalid reports at the individual level is limited (Black, 2000a). The limitation of Goldberg cut-off technique when single PAL is applied to all studied persons is markedly reduced when the physical activity of the individuals is investigated and they are classified into the corresponding activity level as appropriate PAL values are applied to each activity category. This approach gives a possibility to identify more under-reporters or over-reporters.

Using the proposed PAL values for the different physical activity category by age the calculated cut-offs are the following:

Table 4. PAL values for low, moderate and vigorous activity level by age[a] and the lower and upper cut-off for each PAL value for n=1

Age group (years)	Category of Physical Activity	PAL	Lower Cut-off	Upper cut-off
10-14	Moderate	1.8	1.120	2.892
15-17	Low	1.6	0.996	2.570
	Moderate	1.8	1.120	2.892
	Vigorous	2.0	1.245	3.213
18-69	Low	1.4	0.872	2.249
	Moderate	1.6	0.996	2.570
	Vigorous	1.8	1.120	2.892
70-74	Low	1.4	0.872	2.249
	Moderate	1.6	0.996	2.570

PAL- Physical Activity Level,

[a]: according to EFSA Panel on NDA (EFSA, 2013)

Examples:

A. Evaluation of misreporting at group level

Example studied group: Adolescents of age 15 -17 years with moderate physical activity, number of the studied subjects (n) = 30

- Calculate EIrep: BMRest of the individuals included in the studied group
- Calculate mean EIrep:BMRest for the studied group **= 1.16**
- Calculate the specific lower and upper cut-offs for the studied group. In this case we use n=30 and apply PAL=1.8:

$$Lower\ cut-off\ for\ EIrep{:}BMRest\ > PAL \times \exp\left[SDmin\ \times \frac{S/100}{\sqrt{n}}\right]$$
$$= 1.8 \times e^{\left[-2\times\frac{23.7}{100}/\sqrt{30}\right]} = 1.65$$

$$Upper\ cut-off\ for\ EIrep{:}BMRest\ < PAL \times \exp\left[SDmax\ \times \frac{S/100}{\sqrt{n}}\right] = 1.8 \times e^{\left[2\times\frac{23.7}{100}/\sqrt{30}\right]}$$
$$= 1.96$$

The calculated mean value of EIrep:BMRest for the group (1.16) is much lower than the calculated specific lower cut-off (1.65) that means overall bias of under-reporting in the studied group.

B. Evaluation of misreporting at individual level

Example studied group: Adults of age 18-69 years with low physical activity; number of studied subjects (n) =123

- Calculate the individual EIrep:BMRest of the subjects in the group.
- Calculate cut-offs for low physical activity for this age (18-69 years) for n=1. We apply PAL= 1.4 which is adopted for low physical activity of adults.

$$Lower\ cut-off\ for\ EIrep{:}BMRest\ > PAL \times \exp\left[SDmin\ \times \frac{S/100}{\sqrt{n}}\right]$$
$$= 1.4 \times e^{\left[-2\times\frac{23.7}{100}/\sqrt{1}\right]} = 0.872$$

$$Upper\ cut-off\ for\ EIrep{:}BMRest\ < PAL \times \exp\left[SDmax\ \times \frac{S/100}{\sqrt{n}}\right] = 1.4 \times e^{\left[2\times\frac{23.7}{100}/\sqrt{1}\right]} = 2.249$$

- Compare determined EIrep:BMRest of each studied subject with the calculated lower and upper cut-offs for the corresponding physical activity category.

Subjects with calculated values of the ratio EIrep:BMRest in the interval $0.872 - 2.249$ are classified as plausible reporters. Subjects with individual EIrep:BMRest < 0.872 are categorized as under-reporters, subjects with individual EIrep:BMRest > 2.249 are categorized as over-reporters.

From the studied group included 123 subjects we identify:

18 persons as under-reporters= 14.6%

102 persons as plausible reporters = 82.9%

3 persons as over-reporters = 2.4%.

Following the above described steps, lower and upper cut-off values for estimation of under- and over-reporters should be calculated for every studied population group.

5. Management of the data

In order to avoid possible errors in assessing of under- and over-reporting of food consumption all reported data for dietary intake and physical activity should be carefully checked during the interviews and statistical analyses.

Different strategies are applied for data management when the evaluation of reported energy intake is performed at individual level. Some authors present crude results after under-reporters are excluded (Ferrari et al., 2002), but other researchers directly exclude the identified under-reporters from the studied sample (AFSSA, 2009). However, such an approach introduces a source of unknown bias into the dataset and is not recommended (Gibson, 2005). In the assumption that over-reporting is also present in the results, exclusion only of the presumed under-reporters can bias the results as well (Black et al., 1991).

There are a number of considerations for the identified under-reporters and over-reporters not to be excluded from the sample for the following reasons:

- Under-reporting of EI includes both under-recording and under-eating. A lot of studies have demonstrated that under-eating (dieting) is a significant contributor to systematic bias (Braam et al., 1998). Some of respondents could eat much more than usual during the period of study as well (Black, 2000b). On this basis Black considers that it is more accurate “misreporters” to be described as “providing diet reports of poor-validity” (Black, 2000a).
- There are varieties of factors that contribute to limitations of Goldberg cut-off technique resulted in a possibility to identify only gross bias in EIrep. Even when EIrep is directly compared with

EE, measured by DLW, heart rate monitoring or activity dairy (thus avoiding the limitations of the EI:BMR cut-off) can also identify gross bias (Black, 2000b).

- It has been suggested that low energy reporting may be just as common amongst those with plausible energy intakes as amongst those classically defined as under-reporters (Macdiarmid and Blundell, 1997), so that selectively excluding those with implausible energy intakes could bias the results.

As a consequence, the exclusion of potential under-reporters may create a biased sample.

Possible way of how to handle misreporting of dietary intake could be to analyze all collected data, to compare intakes of the group with and without misreporters and then to use the difference as part of uncertainty evaluation.

A Post hoc analysis of dietary intake data of identified under-reporters and over-reporters should be performed to assess the impact of inadequate reporting on overall food consumption data and dietary exposure.

The prevalence of under-reporters, over-reporters and plausible reporters should be calculated in every age/gender group to estimate the problem of inadequate reporting.

The evaluation of under- and over-reporting is a key factor to improve dietary methodology in the future surveys. Characterization of the sub-groups most likely to misreport their food intake as well as the factors that have impact on misreporting could provide useful information. The analysis for identifying foods that are more susceptible to under-reporting is important for adequate exposure assessment as well.

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