Dietary assessment of athletes: validation of a four-day weighed diet record and a physical activity record

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Summary

Background: The ability to assess the energy intake (EI) and the energy needs of an individual athlete or a group of athletes is of vital importance in the field of sports nutrition. Optimal nutrition may contribute to enhanced performance and recovery from exercise whereas inadequate EI relative to energy expenditure (EE) compromises performance and negates the benefits of training. Therefore, meeting energy needs have become a nutrition priority for athletes. However, the majority of studies looking at athletes' energy balance have found limited agreement between self-reported EI and EE measured using the doubly labelled water (DLW) technique. The discrepancies between EI and EE cast doubt on the validity of self-reported dietary data, which is often used as a basis for the dietary assessment of athletes.

Objective: To investigate the validity of a four-day weighed diet record developed for assessing the dietary intake of Norwegian elite athletes by comparing EI with EE measured with the physical activity monitor SenseWear Pro$_2$ Armband (SWA) in a group of male endurance athletes. In addition, EE estimated from a four-day physical activity record was validated against EE measured with SWA.

Design: The participants completed simultaneously a four-day weighed diet record and a four-day physical activity record. During the same four days, they also measured EE with SWA.

Subjects: Thirty-five Norwegian male athletes being members of National teams in summer sports (rowing, kayaking, orienteering, middle- and long-distance running, cycling and race walking) volunteered to participate and completed the study. However, two participants were excluded due to acute sickness during the monitoring period and defect SWA-measurements. Thus, only 33 athletes were included in the study.

Results: The EI was on average 7.6% (1.3 MJ/d, P = 0.017) lower than the EE measured with SWA (EE_{SWA}). The 95% confidence limits of agreement in a Bland-

Altman plot for EI and EE_{SWA} varied from -7.1 to 4.6 MJ/d. The Pearson correlation coefficient between reported EI and EE_{SWA} was 0.58 ($P < 0.001$). Nineteen athletes (58%) were classified into the same third for both EI and EE_{SWA} whereas two athletes (6%) were grossly misclassified.

In the comparison of EE estimated from the activity record (EE_{record}) and EE_{SWA}, the EE_{record} was on average 13.5% (2.3 MJ/d, $P < 0.001$) lower than EE_{SWA}. The 95% confidence limits of agreement in a Bland-Altman plot for EE_{record} and EE_{SWA} varied from -5.7 to 1.2 MJ/d. The Pearson correlation coefficient between estimated and measured EE was 0.86 ($P < 0.001$). Twenty-two participants (67%) appeared in the same third with both the activity record and SWA. There were no grossly misclassified participants.

Conclusion: The data showed that the four-day weighed diet record and the four-day physical activity record under-estimated the average EI and EE respectively. Moreover, there was substantial variability in the accuracy of the diet record and the activity record at the individual level. The ability to rank individuals according to self-reported EI and EE were found to be good with both methods.

Norsk sammendrag

Bakgrunn: Vurdering av energiinntaket og energibehovet til en individuell idrettsutøver eller en gruppe idrettsutøvere er en sentral problemstilling i fagfeltet idrettsernæring. Et optimalt kosthold kan bidra til å forbedre prestasjon og restitusjon etter trening, mens et utilstrekkelig energiinntak i forhold til energiforbruk vil ha negativ innvirkning på prestasjon og redusere effekten av trening. Å dekke energibehovet har derfor blitt en av prioritetene for idrettsutøvere. Likevel har de fleste studier som har sett på energibalansen til idrettsutøvere, funnet lite samsvar mellom selvrapportert energiinntak og energiforbruk målt med dobbelt merket vann (DLW) metoden. Den observerte differansen mellom energiinntak og energiforbruk sår tvil om validiteten til selvrapporterte kostholdsdata, som ofte blir brukt som grunnlag for den individuelle kostveiledningen av idrettsutøvere.

Formål: Formålet med denne studien var å undersøke validiteten til en fire-dagers veid kostregistrering utviklet for å vurdere kostinntaket til norske toppidrettsutøvere, ved å sammenligne energiinntak med energiforbruk målt med aktivitetsmonitoren SenseWear Pro_2 Armband (SWA) i en gruppe mannlige utholdenhetsutøvere. I tillegg ble energiforbruk estimert fra en fire-dagers aktivitetsregistrering validert mot energiforbruk målt med SWA.

Design: Deltakerne gjennomførte en fire-dagers veid kostregistrering og en fire-dagers aktivitetsregistrering samtidig. I de samme fire dagene målte de også energiforbruket sitt med SWA.

Deltakere: Trettifem norske landslagsutøvere i sommeridretter (roing, kajakk, orientering, mellom- og langdistanse løping, sykling og kappgang) deltok frivillig og fullførte datainnsamlingen. To utøvere måtte imidlertid ekskluderes på grunn av akutt sykdom i løpet av registreringsperioden og feil på SWA-målingen av energiforbruk. Totalt ble 33 idrettsutøvere inkludert i studien.

Resultater: Det gjennomsnittlige energiinntaket for hele gruppen var 7,6 % (1,3 MJ/d, P = 0,017) lavere enn energiforbruket målt med SWA (EE_{SWA}). Øvre og nedre grenseverdi for grad av overensstemmelse mellom de to metodene (gjennomsnittlig differanse ± 2 SD) i et Bland-Altman plott var -7,1 og 4,6 MJ/d. Pearson korrelasjonskoeffisient mellom rapportert energiinntak og EE_{SWA} var 0,58 (P < 0,001). Nitten idrettsutøvere (58 %) ble klassifisert i den samme tredjedelen for både energiinntak og EE_{SWA} mens to utøvere (6 %) ble grovt misklassifisert.

I sammenligningen mellom energiforbruk estimert fra aktivitetsregistreringen (EE_{record}) og EE_{SWA} var gruppegjennomsnittet for EE_{record} 13,5 % (2,3 MJ/d, P < 0,001) lavere enn EE_{SWA}. Et Bland-Altman plott viste at gjennomsnittlig differanse ± 2 SD var -5,7 og 1,2 MJ/d. Pearson korrelasjonskoeffisient mellom de to metodene var 0,86 (P < 0,001). Tjueto deltakere (67 %) ble klassifisert i samme tredjedel med både aktivitetsregistreringen og SWA. Ingen deltakere ble grovt misklassifisert.

Konklusjon: Resultatene fra denne studien viste at fire-dagers veid kostregistrering og fire-dagers aktivitetsregistrering underestimerte henholdsvis energiinntak og energiforbruk. Det var stor variasjon i nøyaktigheten til kostregistreringen og aktivitetsregistreringen på individnivå. Begge metodene viste imidlertid god evne til å rangere individer ut ifra selvrapportert energiinntak og energiforbruk.

Table of contents

List of tables

List of figures

List of appendixes

Abbreviations and definitions

Anteroposterior	From front to back
AR	Actual-reporters
BMI	Body mass index (kg/m^2)
BMR	Basal metabolic rate, the amount of energy expended while at complete rest in a thermoneutral environment, in the post-absorptive state (after a 12-hour overnight fast)
CL	Confidence limits
CV	Coefficient of variation
DLW	Doubly labelled water
EE	Energy expenditure
EE_{record}	Energy expenditure estimated from the four-day physical activity record
EE_{SWA}	Energy expenditure measured with the SenseWear Pro_2 Armband
EI	Energy intake
g	Gram
HR	Heart rate
IC	Indirect calorimetry
kg	Kilogram
kJ	Kilojoule
Mediolateral	Relating to the median (middle) plane and a side
MET	Metabolic equivalent
MJ	Megajoule, 1000 kJ
Olympiatoppen	Resource centre for Norwegian top-level sports

OR	Over-reporters
P_{25}	The 25th percentile
P_{75}	The 75th percentile
REE	Resting energy expenditure
RMR	Resting metabolic rate, the amount of energy expended while at rest, a closely related measurement to BMR but measured under less strict conditions
RQ	Respiratory quotient
SD	Standard deviation
Sports products	Supplements of carbohydrate and protein in the form of drinks, gels, bars and powders
SPSS	Statistical Package for the Social Sciences, computer program used for statistical analysis
SWA	SenseWear Pro_2 Armband, a physical activity monitor
TEE	Total energy expenditure
UR	Under-reporters
VCO_2	Carbon dioxide production (L/minute)
VO_2	Oxygen consumption or oxygen uptake (L/minute)

1. Introduction

1.1 Background

The ability to assess the energy intake (EI) and the energy needs of an individual athlete or a group of athletes is of vital importance in the field of sports nutrition. The fact that optimal nutrition may contribute to enhanced performance and recovery from exercise has resulted in increasing concern about both the quality and the quantity of the diets of many athletic groups. Of special concern is their EI. Inadequate EI relative to energy expenditure (EE) compromises performance and negates the benefits of training (1). Sports that require a high EE, like endurance sports, are especially vulnerable.

1.1.1 Energy needs of athletes

The total energy expenditure (TEE) of an athlete is determined by his or her basal metabolic rate (BMR), the level of activity during training, competition and leisure time, the thermic effect of food, and in some cases, growth (2). For a male athlete, the EE of one hour endurance training of high intensity can be more than 4 megajoule (MJ) (3). The total daily energy requirement of an endurance athlete is consequently high, often more than 20 MJ (3). A study of male cross country skiers showed that they had a mean EE of 30.2 MJ/d (4).

Meeting energy needs is a nutrition priority for athletes (1). According to Burke (2) there are several reasons why the EI of athletes is important (table 1.1).

Table 1.1 Why an athlete's energy intake is of great importance

1. It sets the potential for achieving the athlete's requirements for energy-containing macronutrients, vitamins, minerals and other dietary compounds required for optimal function and health
2. It assists the manipulation of muscle mass and body fat levels to achieve the specific physique that is ideal for athletic performance
3. It affects the function of hormonal and immune systems

Adapted from: Burke LM. Energy needs of athletes. Can J Appl Physiol 2001;26 Suppl:S202-S219.

Many athletes struggle to eat enough food to compensate for their high energy output, especially in the most intensive periods of training (5). The training load generally varies from day to day, and consequently athletes will have days and shorter periods of energy imbalance. A negative energy balance over time will affect performance and recovery from exercise. Insufficient EI may result in the use of body fat and lean tissue as energy sources, and subsequently, possibly loss of muscle mass and reduced strength and endurance (1;6). Additionally, immune, endocrine and musculoskeletal function may be compromised (7;8). At the long-term, nutrient deficiencies may arise and further compromise health (1).

The majority of studies looking at athletes' energy balance have found limited agreement between self-reported EI and EE measured using the doubly labelled water (DLW) technique (9-16). Under-reporting of EI is a general problem and some studies have suggested that under-reporting is even greater as EE increases (12;17-20). The discrepancies between EI and EE cast doubt on the validity of self-reported dietary data. Under-reporting makes it difficult to give appropriate diet recommendations, because the recommendations often are based on self-reported dietary data. As a consequence, performance and health may suffer.

1.1.2 Dietary assessment of athletes

A number of techniques may be used for the dietary assessment of individuals and groups of athletes. These can be classified into two major categories; retrospective and prospective methods. Retrospective methods include 24-hour diet recall, food-frequency questionnaire (FFQ) and diet history. These methods recall past consumption. Prospective methods include duplicate portion, estimated and weighed diet records and measures food intake at the time of consumption. The application, strengths and limitations of these methods have been extensively reviewed elsewhere (21-23).

A three to four day estimated diet record is the most widely used approach in the clinical practice of sports nutrition (2;24;25). However, weighed records, modified diet histories and collections of single or multiple 24-hour diet recalls are also commonly used (20;25). When performing an estimated diet record, the subject is asked to keep a detailed record of all foods and drinks consumed during the recording period. The amount of each food item is quantified by describing portions in terms of household measures (glasses, spoons etc.), in dimensions or number of items of predetermined size (20;26). This method is relatively simple and less demanding for the athlete compared to the weighed dietary method (26).

Despite the advantages of the estimated diet record, it is less accurate than the weighed method provided that respondents are trained and motivated (25). The weighed diet record follows the same procedure as the estimated method, except that the subject has to weigh each item of food and drink at the time of consumption, rather than estimate. The weighing procedure can be demanding and is highly dependent on subject co-operation. The compliance may be poor and subjects may alter their food patterns to simplify the recording, thereby introducing bias (26).

An alternative approach to assess the EI and energy needs of athletes is to measure their EE (26). Measuring EE will not give any qualitative information about the diet. However, it will make a basis for dietary plans and guiding of athletes regarding how much food is needed to achieve energy balance. Practical ways of assessing EE in everyday life include heart rate monitors, physical activity monitors like accelerometers, and physical activity questionnaires and records (27;28).

1.1.3 The search for an ideal method to assess the energy intake of athletes

The ideal method to assess the EI of athletes should provide as accurate data as possible while placing minimal burden on both the athlete and the nutritionist. The Department of Sports Nutrition at the Norwegian Olympic Sports Centre, Olympiatoppen, has developed a four-day weighed diet record as a tool for assessing the diet of Norwegian elite athletes. Additionally, a self-developed physical activity record for the estimation of EE is considered for use at Olympiatoppen.

In order to be able to give athletes appropriate nutritional recommendations, it is important to have knowledge about the accuracy of dietary methods used in the clinical practice. To test whether a four-day weighed diet record provides reasonable estimates of true EI of elite athletes, and whether an activity record can give reasonable estimates of EE, these methods needs to be validated. The purpose of this study is to evaluate one established and one potential method for collecting data on EI and EE of athletes at the Norwegian Olympic Sports Centre.

1.2 Validation of dietary assessment methods

It is crucial for a dietary survey that the method gives accurate data. Validation studies are performed to give knowledge about how good a method is to measure the true dietary intake, and to investigate which types of error that may be associated with the method. Today there is no method for dietary assessment available that can measure the diet of an individual or a group of individuals without error. This inaccuracy can affect the interpretation of the results of a dietary survey, or the interpretation of the relation between diet and health (29). In the sports nutrition setting, it can affect the interpretation of the relation between diet and physical performance. To avoid wrong conclusion due to incorrect data, it is therefore of high importance to investigate the quality of these methods. The quality of a dietary assessment method can be expressed by the means of its validity and reproducibility. In this thesis only validity is discussed.

1.2.1 Definition of validity

Validity is an expression of the degree to which a measurement is a true and accurate measure of what it is designed to measure (30). To illustrate; a valid diet record is one in which the subject records exactly what he/she ate and drank during the period of study and this is what he/she would have eaten and drunken if no investigator had intervened (26;31). A study is considered to be valid if the findings can be taken as being a reasonable representation of the true situation (30).

1.3 How to validate a method

Validity can be investigated by comparing the results from a new or alternative method (test method) with the results from a true external reference method. In nutrition, no such reference method exists. It is not possible to have an absolute measure of the true dietary intake. Because every measurement of dietary intake includes some bias, only the "relative" validity can be assessed when two dietary methods are compared (30).

The results from the test method can be compared against the results from another method that is assumed to be more accurate than the test method. The weighed dietary record has often been assumed to be the gold standard in validation studies of dietary intake, and has thus been frequently used as a reference method (31). The results from the test method can also be compared against objective biological markers of intake (29;31). There are two types of biomarkers; recovery and concentration biomarkers. Recovery biomarkers have a known quantitative time-associated relation between dietary intake and recovery (excretion) in human waste, and can be used for validating absolute dietary intake. Examples of recovery biomarkers are DLW which is a biomarker for TEE and urinary nitrogen which is a biomarker for protein intake (32).

To assess whether the validity of a method is satisfactorily, several criteria have to be fulfilled (29). As already mentioned, the reference method must be regarded as more accurate than the test method. Secondly, the reference method has to measure food intake at the same level as the test method. If the test method gives information about the intake at group level, so the reference method has to do. Furthermore, the test and the reference method should not contain the same type of error. However, when validating one dietary assessment method against another, the two methods often contain both independent and dependent error. Recovery biomarkers as reference have the advantage that they do not contain the same error as a dietary method. Ideally, one should choose two reference methods and compare the results from the test method with the results from both another dietary method and a valid recovery biomarker. Whether to include one or two reference methods is often a matter of resources (29;32).

Another important aspect is the sequence in which the reference and the test method are administered. The test method should be administered first to avoid any influence on the reference method. Finally, the participants in the validation study should be a sample from the population where the test method is planned to be used. Due to a great workload often associated with participation in validation studies, it can be difficult to obtain a representative sample. Those who are willing to participate, are generally more motivated than the population the method is directed to (29). It is important to have this in mind when interpreting the results.

1.4 Validation of energy intake

Incorrect reporting of food intake, primarily under-reporting, is a major problem in dietary surveys and represents a pressing issue for nutritionists in general as well as sports nutritionists. From the growing body of research it is now apparent that there is a generalized under-reporting of food intake in many subject groups, including children, teenagers, elderly, obese individuals, military personnel, trekking explorers and athletes (14;33). Among athletes, under-reporting differs widely from 0% in male cross country skiers to 43% in elite female swimmers, as presented in a review by Hill and Davies (14).

Although many factors are associated with under-reporting, the reasons for this phenomenon are not clear. The term under-reporting involves both conscious and unconscious omission of food items and under-eating (dieting) (34). Some studies suggest that under-reporting is more prevalent in women than in men. In a study of Norwegian males and females aged 16-79 years, Johansson et al. (35) found that significantly more women (45%) under-reported their EI compared to men (38%). This is in accordance with other national surveys (36-38) and may also be the case among athletes. In a study of Greek swimmers and water polo players, twice as many women under-reported compared to men (39).

The highest degree of under-reporting is observed among female athletes but fewer studies of male athletes are available (14). The higher under-reporting in women is linked to the increased prevalence of weight consciousness and thus dietary restraint in this group. This is especially true in sports where body weight affects performance and where there is a distinctive advantage of being lean (2;12).

Studies have also shown considerably under-reporting of EI among obese subjects, and that the degree of under-reporting is positively correlated with degree of obesity (14;40). Similarly, it has been observed that the larger the body mass index (BMI) of an athlete the greater the difference between reported EI and DLW-values of EE (12). This indicates that perceived body image may influence the accuracy in reporting food consumed. There also seems to be a trend for absolute under-reporting to increase as EE increases. One suggested explanation for this is that athletes consuming large amounts of food perhaps tend to forget to report a substantial portion of it (20). Educational level, income and socio-economic status are other factors related to under-reporting (14).

To document and deal with the incorrect reporting of food intake it is important to validate EI against an objective criterion method, such as a measurement of EE. The use of EE for validating EI is based on the principle of energy balance and the fundamental physiological equation:

EI = EE ± changes in body stores

Because energy can neither be created nor destroyed, EI must equal EE unless there is a change in body energy stores (41). At the group level and in the time scale of a dietary assessment, body weight can be regarded as constant, and therefore, mean EI must equal mean EE (26).

1.5 Methods for validation of energy intake

Several methods are developed to measure EE and can accordingly be used for validation of EI. However, these methods vary in accuracy, feasibility and costs. There are three types of EE assessment methods that can be distinguished: criterion methods, objective methods and subjective methods. Criterion methods like DLW and indirect calorimetry (IC) are the most reliable and valid measurements against which all other EI and EE assessments methods should be validated, but they also hold important drawbacks. Objective EE assessment methods include activity monitors and heart rate monitors. Finally, questionnaires and activity diaries are considered subjective methods (28). The following section gives a brief description of the techniques introduced above.

1.5.1 The doubly labelled water technique

The DLW technique is the gold standard for measuring EE under free-living conditions. The subject is given a dose of water enriched with the stable isotopes deuterium (^{2}H) and oxygen-18 (^{18}O). Body fluid samples, usually urine samples, are collected at baseline before administration of the dose and subsequently either daily (multipoint method) or at the beginning and end of the measurement period (two-point method) (42). The urine samples are analysed by isotope ratio mass spectrometry to determine the rate of disappearance of each isotope from the body. Deuterium is lost in water only, whereas oxygen-18 is lost in both water and carbon dioxide (CO_2). The difference between the two disappearance rates can therefore be used for calculating CO_2 production. By applying standard indirect calorimetric equations and an estimate of the respiratory quotient (RQ), TEE can be calculated (43).

The measurement period is commonly 14 days, but periods of 7-21 days have also been used. In validation studies, the DLW method has shown accuracy in the order of 1-3% and precision of 2-8%. More details about the DLW technique is presented elsewhere (44).

DLW is a useful method for monitoring EE in the field because it places minimal burden on the subjects and no restrictions on daily life. Unfortunately, the requirement of laboratory facilities and the costs of the enriched water samples and analysis limit this method for research use. It is not suitable as a routine tool for validating EI data (30). Another disadvantage about the DLW technique is that it only gives an estimate of the mean EE during the period of measurement and not day-to-day or hour-by-hour EE.

1.5.2 Indirect calorimetry

IC is a commonly used method for assessing EE in humans (6). The method estimates EE by determining the volume of oxygen consumed (VO_2) and the volume of CO_2 produced (VCO_2) over a given time period. The equipment varies, but most commonly the subject breathes into a mouthpiece or a ventilated hood through which the subjects expired gases are collected. Knowing the VO_2 and VCO_2, different formulae can be used for calculating EE. IC can also provide information concerning the relative contribution of the different energy-containing macronutrients to the TEE (6).

IC is most often used for measuring resting energy expenditure (REE) and for determining the required level of EI in a hospital setting. The method can also be used for measuring EE during exercise, however, due to the uncomfortable mouthpiece and the nose clip the subject needs to wear, it is not suitable for long periods of measurement (45). The measurement equipment makes the situation artificial, and the method can thus not give an optimal TEE measurement of a normal life situation. Even though IC represents one of the most valid measurements of EE (28), it is not an appropriate method for measuring the EE of athletes for several days.

1.5.3 Heart rate monitors

Estimating EE from heart rate (HR) is a relatively inexpensive and simple method to perform. It has therefore been investigated in many studies (46-49), including studies of athletes (50;51). The method is based on the assumption of linear correlation between HR and VO_2 during most activities (27). When the individual relationship between HR and VO_2 is determined, measurement of VO_2 can then be used for calculating EE at different HR's (52).

One of the main limitations of this method is that during very low or very high intensities, the relationship between HR and VO_2 becomes non-linear. Also, during quick changes in intensities the HR response lags behind. This will introduce a small error when HR is used for predicting EE. However, it appears to be a general consensus that the HR method provides satisfactory estimates of average EE at the group level (46;47;49;53).

1.5.4 Accelerometers

Accelerometers are electronic motion sensors that measure dynamic body movement in terms of acceleration (54). Acceleration is the change in velocity with respect to time (m/s^2). The accelerometers are usually uniaxial or triaxial. Uniaxial accelerometers measure acceleration in one direction, usually in the vertical plane. Triaxial accelerometers measure acceleration in the anteroposterior, mediolateral and vertical direction and thus provide better precision (55). The devices can be worn on the waist, hip, low back, wrist or ankle, however the waist is the most common position because it is closest to the centre of the body (54).

The disadvantage with accelerometers is that they are insensitive to certain activities like static work, stair climbing and bicycling (56). Different brands of accelerometers are commercially available, but in a recent review of eight different devices only one showed reasonable correlation with DLW derived EE (57).

1.5.5 SenseWear Pro$_2$ Armband

The SWA (Body Media, Pittsburg, PA., USA) is a newly developed multiple-sensor device to estimate EE (figure 1.1). The device is a wireless armband which combines five different sensors and is worn in contact with the upper arm skin surface. According to information provided by the manufacturer (www.bodymedia.com), the armband incorporates a variety of measured parameters (accelerometry, skin temperature, near-body temperature, heat flux, galvanic skin resistance) and demographic characteristics (gender, age, height, weight) into proprietary algorithms to estimate EE. The biaxial accelerometer measures motion and provides information about body position. The skin temperature sensor and near-body temperature sensor consist of sensitive thermistors in contact to the skin relying on change in resistance with changing temperature. The heat flux sensor uses the difference between skin temperature and near-body temperature to assess heat loss from the body. The galvanic skin response sensor measures the conductivity of the skin between two electrodes in contact to the skin. The conductivity of the skin varies according to physical and emotional stimuli. For instance, when you sweat, the skin becomes more electrically conductive. See figure 1.1 for illustration of the armband and its sensors.

Figure 1.1 The SenseWear Pro_2 Armband (SWA)

1. Two-axis accelerometer
2. Skin temperature sensor
3. Near-body temperature sensor
4. Heat flux sensor
5. Galvanic skin response sensor

SWA has been validated against IC and the DLW method in several studies and among different subject groups (58-70). The results from these studies are somewhat ambiguous, but when compared to other activity monitors SWA seems to represent one of the best estimates of TEE (60;69).

The design of SWA (wireless, small and lightweight) makes it comfortable to wear, which is especially important when assessing physical activity in athletes. The main limitation for the use in athletes is that it can not be used during any water activities.

1.5.6 Physical activity questionnaires

Physical activity questionnaires, either self-reported or interviewer-administered, are the most common tools for assessment of physical activity (71). Although the methodology is cheap and allows large-scale application, the reliability and validity is low (72). In general, people tend to over-estimate physical activity and under-estimate sedentary activity (73). Activity questionnaires can be used as an activity-ranking instrument (71), but have limited application to estimate daily EE (74-76).

1.5.7 Physical activity records

Another practical way to estimate EE is by the means of an activity record and the factorial approach. This method calculates TEE using information on BMR, the time devoted to different activities and the energy cost of each activity (BMR-multiple) throughout 24-hour periods (77). The average energy costs of different activities can be found in various reference lists. The values from the reference lists are mainly based on data from IC-measurements of a wide range of activities, where the EE is expressed as either multiples of BMR (78) or multiples of one metabolic equivalent (MET) (79;80). One MET is considered a resting metabolic rate (RMR), which for the average adult is approximately 1 kcal per kg bodyweight per hour or 3.5 ml oxygen per kg bodyweight per minute. Therefore, METs, similarly to BMR-multiples, express energy costs of physical activities as multiples of RMR (79;80). RMR is considered approximately equal to BMR, and these terms are here used interchangeably.

Activity records have the advantages that they are inexpensive and do not rely on complicated methodology. However, the accuracy of an activity record is highly dependent on the co-operation of the subject. To be accepted, the record has to be very simple. A such simplified method was originally described by Bouchard et al. 1983 (81). Subsequently, different modifications of this method have been used for the assessment of EE. They vary from three to seven days, including one Saturday or Sunday, and a day is commonly divided into 96 periods of 15 minutes each (50;82;83). Usually, activities are classified on a scale from 1 (rest) to 9 (heavy exercise) with a corresponding energy cost derived from a comprehensive review of literature. Even though the activity record is an inexpensive method, it is time-consuming and has shown limited accuracy (83), especially in athletes with a high EE (50).

2. Objective and research questions

2.1 Objective

In the present study the aim is to investigate the validity of a four-day weighed diet record developed for assessing the dietary intake of elite athletes. EI estimated from the diet record is compared with EE measured with SWA in a group of healthy male athletes in endurance sports. In addition, EE estimated from a four-day physical activity record is validated against EE measured with SWA. The validity at both the individual level and the group level is considered in the study.

2.2 Research questions

The following research questions have been formulated:

Main:

1. To what extent is the EI estimated from a four-day weighed diet record in accordance with the EE measured with SWA among Norwegian male elite athletes in endurance sports?

2. To what extent is the EE estimated from a four-day physical activity record in accordance with the EE measured with SWA?

Secondary:

3. To what extent do Norwegian male elite athletes in endurance sports under-report or over-report their EI?

4. Are there any differences in the intake of macronutrients and in the intake of selected food items and food groups in the diet between those who incorrectly report (under- or over-report) their diet and those who do not?

3. Subjects and methods

3.1 Subjects

The participants in the present study were recruited from the following summer sports classified as endurance sports: rowing, kayaking, orienteering, middle- and long-distance running, cycling and race walking. Only males were invited to participate. Invitation letters were sent to a total of 71 athletes.

3.1.1 Criteria for participation

There were three inclusion criteria to participate in the study. The athletes had to 1) be 18 years or older, 2) be a member of a national team in a summer endurance sport, and 3) be healthy and free from injuries in the data collection period.

Participants who were sick or injured, and thus could not exercise as usual, were excluded from the study.

3.1.2 Participation

Thirty-five male elite athletes volunteered to participate in the study. This amount to 49% of those who where invited. The participation rate was 44-89% in all sports, except in cycling where only 22% of the invited wanted to participate. The highest participation rates were observed for rowing, kayaking and orienteering, with 89%, 60% and 58% respectively.

All 35 athletes completed the diet- and activity registrations. However, two subjects were excluded due to acute sickness during the registration period and defective SWA-measurements of EE, respectively. Thus, a total of 33 athletes were included in the study.

3.2 Methods

3.2.1 Design

The study was approved by The National Committees for Research Ethics in Norway (appendix 1) and Norwegian Social Science Data Services (appendix 2).

Participants were recruited consecutively from September 2008, and the data collection was completed from September 2008 to January 2009. The study was conducted in the athletes' training season, which is the part of the year without competitions.

Before recruitment of participants, address lists of male members of the national team in each sport were obtained from the national sport federations. The athletes received a written invitation to participate in the study by mail (appendix 3). Those who were interested in participating were asked to return a written consent in a post paid self-addressed envelope (appendix 3). The investigator (the master student) then contacted each participant to arrange when and where to meet to include them in the study. The athletes resided in or nearby Oslo were asked to meet at Olympiatoppen at an optional day and time. Athletes resided farther away were offered to meet the investigator in the city nearest to their home, so the inclusion would involve as little load as possible for the athlete.

The participant had to meet the investigator both before and after the data collection period. Body weight was measured both times. After thorough instructions at the first meeting, the athletes performed a weighed diet record, an exercise registration, and a physical activity record for four days (appendix 4). In the same four days, they also wore the physical activity monitor SWA to measure their EE (appendix 5). At the second meeting, the record notebooks were checked for any obscurities and the participant had to answer some control questions to the diet- and activity registration (appendix 6). At this meeting the participants were also rewarded with a cook book for athletes.

When all results were processed, the athletes received a written evaluation of their diet by mail. Appendix 7 shows an example of a written feedback given to one of the participants. The participants were invited to contact the investigator if they had any questions to the feedback or wanted to make an appointment to go through the results.

3.2.2 Body measurements

Body measurements of the participants included weight and height. These data were used for calculating BMI and for estimating BMR. Weight and height were also applied to the software when downloading data from the SWA.

Body weight was measured both before and after the data collection period, to the nearest 0.1 kg using the Seca Alpha 770 electronic weighing scale. The athletes were weighed in underwear and without shoes. The mean of the two measurements of body weight is presented in the results. Height was partly self-reported (n=12) and partly measured to the nearest 0.1 cm using the Seca electronic stadiometer (n=21). BMI was calculated as body weight (mean of two measurements) divided by the square of height (kg/m^2).

3.2.3 The test methods

Four-day weighed diet record

The four-day weighed diet record (appendix 4) used as the main test method in this study is developed for the use among elite athletes in Norway.

The participants were provided with record notebooks and a digital kitchen scale (Soehnle Page) measuring with a precision of ± one gram and a maximum of 5000 grams. The digital kitchen scale also had a tare function to make the weighing of meals and composite dishes easier for the participants.

The athletes were given both practical and written instructions on how to weigh and describe in detail the consumption of food and beverage, and to measure and note all foods wasted and not eaten. It was stressed that the purpose of the study was to measure the habitual food intake and that any temptations to change the diet in order to simplify or make the diet healthier should be counteracted. They were also instructed not to make an attempt to reduce or increase their bodyweight during the registration period. Each participant was invited to contact the investigator by phone or by email if any questions appeared during the four days of recording.

The data collection had to be carried out when the athletes were in Norway, and preferably when they lived at their place of residence. The measurement period consisted of four consecutive days including one Saturday or Sunday; either from Wednesday to Saturday or from Sunday to Wednesday. During four days, the participants recorded all their consumption of food items, drinks and dietary supplements in grams or millilitres. They were asked to give time of meal and brand name and product name of every food item. Additionally, they were asked to provide a complete description of the method for cooking and recipes for composite dishes. If foreign or rare food items were eaten, they were asked to enclose the packing with nutrient content. If meals were eaten outside the home with no chance of weighing the food, the athletes were instructed to make a note of the menu and describe the food eaten in household measures.

When the participants handed back their record notebooks, the notebooks were read through by the investigator to check for possible obscurities which then could be solved with the participant. At the same time, they had to answer some control questions about the diet during the recording period, any change in bodyweight, sickness and use of medicine (appendix 6). Any use of dietary supplements and sports products was also checked with regard to type, dosage and frequency of use.

The dietary assessment included results on consumption of food items, drinks and supplements, intake of energy and nutrients, meal pattern, time for meals in relation to exercise, and consumption of food and drink before, during and after exercise. It is only the intake of energy, macronutrients and selected food items that are described in this work. The remaining data were used in the nutritional feedback to the participants.

The daily intake of energy and macronutrients was calculated using a food database and software system (Mat på Data, version 5.0). This database was originally developed at a Norwegian association for diet and health (Landsforeningen for kosthold og helse) and later taken over and updated by the Norwegian Food Safety Authority. The food database is based on the official Norwegian Food Composition Table (2006). The food database was manually supplemented with data on new food items when needed by the investigator. The new food items added were mainly sports products, ready-made food and newly launched products. Nutrient information was collected from the packing, producer or food databases in other countries.

Microsoft Office Excel 2003 was used for alphabetically sorting of food items eaten by each participant, and for calculating mean daily intake in grams of selected food items and food groups. These data was used in the comparison of food intake between under-reporters (UR), actual-reporters (AR) and over-reporters (OR). In the same comparison, the category fruit and berries included only fresh fruit and berries. Vegetables did not include potatoes. Milk included both milk and cultured milk used as drink, in coffee or tea, or on breakfast cereals. In the category sports products, supplements of carbohydrate and protein (bars, powders, drinks and gels) were included.

Exercise registration

The participants recorded all exercise performed during the same four days as the diet record. The Department of Sports Nutrition at Olympiatoppen has composed a scheme for registration of exercise for use in the combination with the diet record and an activity registration (appendix 4).

Both practical and written information on how to fill inn the scheme were given at the inclusion meeting. The participants were supposed to make notes on time for exercise, what kind of exercise performed (endurance, strength, technique etc.), intensity level and total duration of each exercise in minutes. On this scheme they were also supposed to record any intake of food and liquid during the exercise.

The main purpose of the exercise registration is to calculate total minutes of exercise, and assess the intake of liquid and carbohydrates per hour exercise. This is important for the individual feedback to the athletes. Detailed information about exercise is also useful for the application of appropriate energy costs of activities in the activity record described below.

Four-day physical activity record

A four-day physical activity record was designed to estimate EE. In the record, a day was divided into 48 30-minute intervals. The athletes were asked to precisely fill in the kind of activity they performed every 30 minutes during the four days of registration (appendix 4). Both practical and written information were given on how to fill in the scheme and how to define the activities, e.g. sleeping, lying down, sitting, walking, light exercise, moderate exercise, hard exercise etc. The activity diaries were reviewed with the participants at the time of delivery.

Physical activity was categorized into six categories, according to Manore and Thompson 2000 (84) (table 3.1).

Table 3.1 Approximate energy costs expressed as multiples of basal metabolic rate (BMR) for six activity categories

Activity category	Examples	Energy cost per unit of time of activity
Resting	Sleeping, reclining	BMR × 1.0
Very light	Seated and standing activities	BMR × 1.5
Light	Slow walking, house-cleaning	BMR × 2.5
Moderate	Moderate walking, slow cycling, stretching, carrying a load	BMR × 4.0
Strenuous	Walking uphill with a load, jogging/running, weight training, moderate pace exercise	BMR × 7.0
Very strenuous	Fast running, race pace	BMR × 10.0

Adapted from: Manore M, Thompson J. Energy requirements of the athlete: assessment and evidence of energy efficiency. In: Burke L, Deakin V, eds. Clinical Sports Nutrition. Roseville: McGraw-Hill Book Company Australia Pty Limited 2000:124-45.

When estimating the EE, the total hours spent in each activity category was multiplied with the given average energy cost for that category (table 3.1). This result was further multiplied with estimated BMR divided at 24 hours. BMR was estimated from the Harris-Benedict equation for males:

$$BMR = 66.47 + (13.75 \times weight) + (5 \times height) - (6.76 \times age)$$

The energy costs of all activities performed during a day was then added up to give an estimate of TEE that day. See table 3.2 for an example of calculation. The mean estimated EE of four days is presented in the results.

Table 3.2 Example of calculation of total daily energy expenditure for one day based on the four-day activity record

BMR estimated from the Harris-Benedict equation: 7432 kJ/day (7.4 MJ/day)

Activity category	BMR[a]-multiple	Time spent at the activity (hours)	Calculation	Total energy cost of each activity (kJ)
Resting	1.0	11.5	1.0 × 11.5 × 7432 / 24	3561
Very light	1.5	8.0	1.5 × 8.0 × 7432 / 24	3716
Light	2.5	2.0	2.5 × 2.0 × 7432 / 24	1548
Moderate	4.0	1.5	4.0 ×1.5 × 7432 / 24	1858
Strenuous	7.0	1.0	7.0 × 1.0 × 7432 / 24	2168
Very strenuous	10.0	0	10.0 × 0 × 7432 / 24	0
Total		24		12 851

[a]Basal metabolic rate.

3.2.4 The reference method

SenseWear Pro$_2$ Armband

As recommended by the manufacturer, the athletes wore the armband on the right arm over the triceps muscle at the midpoint between the shoulder and the elbow. The armband was worn during the same four days as the athletes performed the weighed diet record and the activity record. Both practical and written information about the SWA was given to participants (appendix 5). The investigator illustrated where and how to place the armband. It was stressed that the armband had to be put on before midnight prior to the first recording day and removed after midnight at the last recording day. The purpose of this was to get complete 24-hour measurements during the four days of recording. All participants were instructed to remove the armband only for bathing purposes or any water activities. They were also asked whether it was likely that they were going to perform any water activities during the test period, but this was not likely for none of them.

The data from the monitor was downloaded with software developed by the manufacturer (Innerview Professional Research Software Version 5.1, BodyMedia Inc., Pittsburgh, PA, USA). Descriptive characteristics (sex, age, height, and weight) were entered into the software program before initializing the monitor. When downloading the data, the software provided percentages of on-body time. A threshold of 95% on body time was used for including an individual in the data analyses.

3.2.5 Statistical methods

Sample size calculation for the study was based on calculation of a standardized difference (2δ/SD), using a standard deviation (SD) of EI of 2 MJ and a clinically relevant difference (δ) of 1 MJ (85). Choosing a significance level of 0.05 with 80% power, a nomogram for calculating sample size (85) estimated that we needed 32 subjects to be sure to detect a mean difference of 1 MJ between EE measured with SWA and EI assessed with the weighed diet record.

Statistical analyses were performed using SPSS version 16.0 (SPSS inc., Chicago, IL, USA). Results were considered to be statistically significant at $P < 0.05$.

The data of the whole group (n=33) were approximately normally distributed, and parametric statistical analyses have been used for this group. These data are presented as mean, median and SD. Mean differences between the test methods and the reference method were analysed using the Student *t*-test for paired samples.

The agreement between the test method and the reference method at the individual level was analysed by the method proposed by Bland and Altman (86), using a plot of the difference between the two methods against the average of the measurements. This type of plot shows the magnitude of disagreement, spots outliers and any trend.

Furthermore, the ability of the test methods to rank individuals according to EI and EE were assessed using Pearson correlation coefficient and by classification of EI and EE in thirds.

The accuracy of reported intake was calculated by expressing the ratio of EI:EE, for which a value of 1 would mean complete agreement between EI and EE. Actual-reporters (AR) were defined as having EI:EE in the range of 0.80-1.20, under-reporters (UR) a ratio less than 0.80, and over-reporters (OR) a ratio larger than 1.20. Comparisons between UR and AR were conducted using non-parametric statistical analyses, since the data of the small group of UR were not normally distributed. These data are presented as median values with the 25th and 75th percentiles (P_{25}, P_{75}) to describe variability. Differences between UR and AR were tested using the Mann-Whitney test. The results for the OR-group is presented in the tables but were not included in the statistical testing because only two subjects were in this group.

4. Results

4.1 Sample

Thirty-three male endurance athletes were included in the study. All participants fulfilled the requirement of wearing the SWA more than 95% of the time of registration. The distribution of participants from different sports is shown in table 4.1.

Table 4.1 Number of participants from different sports

	Male athletes (n=33)
Rowing	8
Middle- and long-distance running	8
Orienteering	7
Kayaking	4
Cycling	4
Race walking	2

The athletes' mean and median age, height, weight, BMI and exercise hours per day are outlined in table 4.2.

Table 4.2 Physical characteristics of the participants

	Total (n=33)		
	Mean	Median	SD[a]
Age (years)	22.5	21.3	3.9
Height (cm)	184.8	183.0	6.8
Weight (kg)	75.9	73.8	8.8
BMI[b] (kg/m^2)	22.2	22.1	1.7
Exercise (hours/d)	1.9	1.9	0.6

[a]Standard deviation.
[b]Body mass index.

Initial body weight did not differ significantly from the body weight observed following the four-day assessment period (75.9 (8.8) kg vs. 75.8 (8.9) kg (mean (SD)), $P = 0.258$).

4.2 Comparison of energy intake estimated from the four-day weighed diet record and energy expenditure measured with the SenseWear Pro_2 Armband

Information on the reported EI, measured EE (EE_{SWA}) and the differences between the two methods are presented in table 4.3. The group average EI was significantly lower (-1.3 MJ/d) than the EE measured with SWA. The difference between the two methods among individuals varied from -8.8 to 3.3 MJ/d.

Table 4.3 Energy intake (EI) estimated from the weighed diet record, energy expenditure measured with the SenseWear Pro_2 Armband (EE_{SWA}) and the relationship between EI and EE_{SWA}

	Total (n=33)		
	Mean	Median	SD[a]
EI (MJ/d)	15.8	14.8	3.3
EE_{SWA} (MJ/d)	17.1	16.1	3.1
EI-EE_{SWA} (MJ/d)	-1.3[b]	-1.2	2.9
EI:EE_{SWA} (MJ/d)	0.93	0.92	0.16

[a]Standard deviation.
[b] $P = 0.017$ (student *t*-test).

As illustrated in figure 4.1 the discrepancy between EI and EE_{SWA} was largest among kayakers and cyclists (3.1 and 2.8 MJ/d respectively). The best agreement between reported EI and EE_{SWA} was observed among orienteerers (0.4 MJ/d difference).

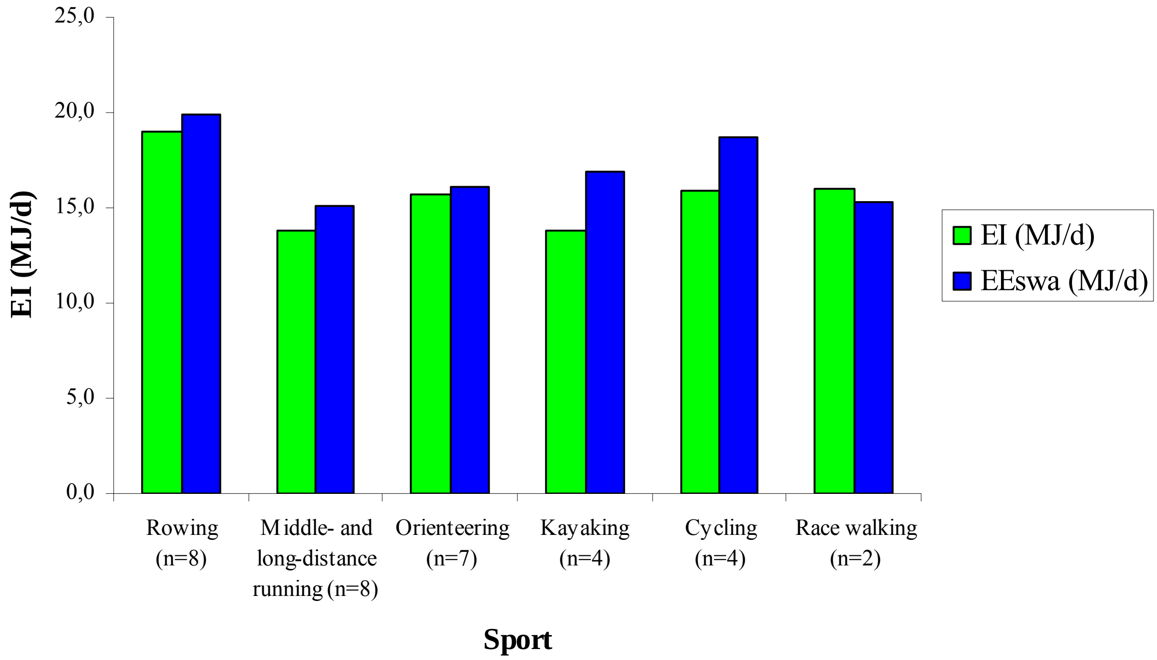

Figure 4.1 Comparison of energy intake (EI) estimated from the weighed diet record and energy expenditure measured with the SenseWear Pro_2 Armband (EE_{SWA}) within and between the different sports

A Bland-Altman plot, showing the difference between EI estimated from the weighed diet record and EE measured with SWA plotted against the mean of the two methods, is presented in figure 4.2. The plot illustrates that both under-reporting and over-reporting of EI occurred. The 95% confidence limits (CL) of agreement varied from -7.1 to 4.6 MJ/d (± 2 SD), which indicates wide discrepancies between the two methods for individual subjects. However, the plot does not indicate that differences tended to increase as absolute EI increased.

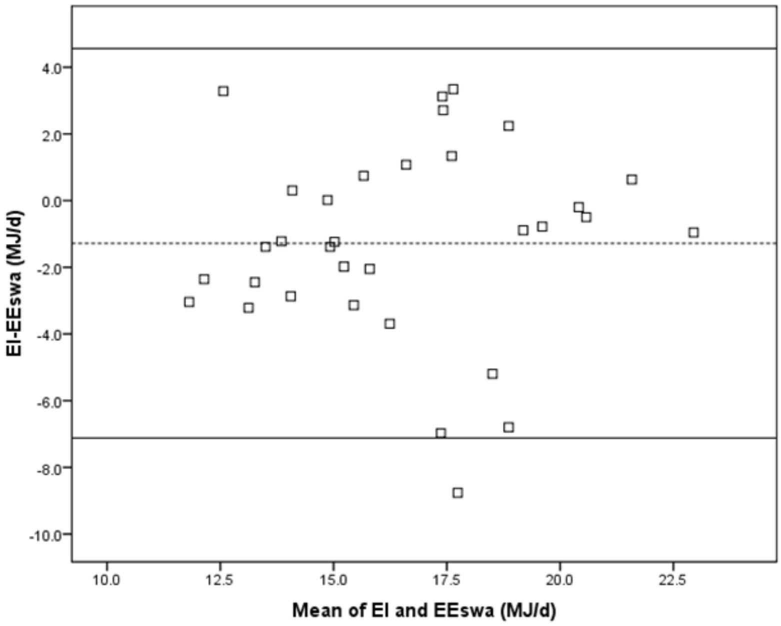

Figure 4.2 The difference between energy intake (EI) estimated from the weighed diet record and energy expenditure measured with the SenseWear Pro$_2$ Armband (EE_{SWA}) plotted against the mean of the two methods. (·····), mean difference between the two methods; (—), SD 2 limits of agreement

The Pearson correlation coefficient between reported EI and EE_{SWA} was 0.58 ($P < 0.001$). Figure 4.3 shows the association between EI and EE_{SWA}.

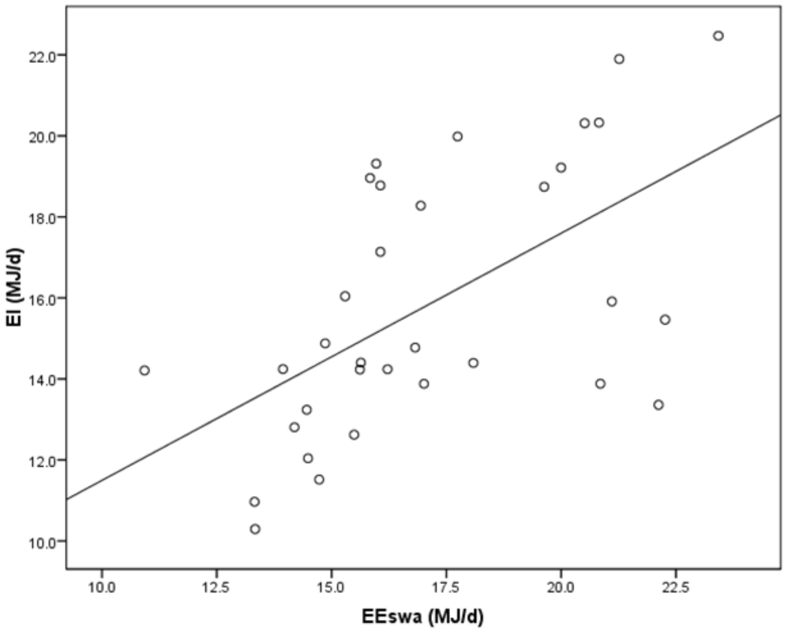

Figure 4.3 Energy intake (EI) estimated from the weighed diet record plotted against energy expenditure measured with the SenseWear Pro$_2$ Armband (EE_{SWA}). (—), linear regression line

There was no significant relationship between BMI and the ratio of EI and EE_{SWA} ($EI:EE_{SWA}$) ($r = 0.097$, $P = 0.591$).

The agreement between EI and EE_{SWA} as determined by classifying individuals into thirds is illustrated in table 4.4. The distribution showed that 19 athletes (58%) appeared in the same third for both EI and EE_{SWA}. Two athletes (6%) were grossly misclassified, that means they were placed in the lowest third with one method and in the highest third with the other method.

Table 4.4 Distribution of participants in thirds with regard to energy intake (EI) estimated from the weighed diet record and energy expenditure measured with the SenseWear Pro_2 Armband (EE_{SWA})

		Thirds EE_{SWA}			
		1	2	3	Total
Thirds EI	1	**8**[a]	1	2	11
	2	3	**5**	3	11
	3	0	5	**6**	11
	Total	11	11	11	33

[a] The number of persons classified into the same third for both EI and EE_{SWA} is outlined with bolded font.

Accuracy in reporting

Among the 33 participants, 24 athletes (73%) were classified as AR, 7 athletes (21%) as UR and 2 athletes (6%) as OR. Table 4.5 shows a comparison of physical characteristics, EI and EE between the three groups.

Table 4.5 Physical characteristics, energy intake (EI) estimated from the weighed diet record, energy expenditure measured with the SenseWear Pro_2 Armband (EE_{SWA}) and the relationship between EI and EE_{SWA} among under-reporters (UR), acceptable-reporters (AR) and over-reporters (OR)[a]

	UR (n=7)		AR (n=24)		OR (n=2)	
	Median	P_{25}, P_{75}[b]	Median	P_{25}, P_{75}	Median	P_{25}, P_{75}
Age (years)	20.5	(19.7, 20.8)	23.0	(19.9, 26.1)	20.6	(20.2, 20.9)
Height (cm)	182	(179.5, 190.0)	185.8	(180.3, 190.5)	181.5	(181.0, 182.0)
Weight (kg)	73	(71.6, 86.0)	73.8	(69.7, 82.9)	75.2	(73.8, 76.6)
BMI (kg/m^2)	22.2	(21.8, 23.8)	21.9	(21.2, 23.2)	22.9	(22.3, 23.4)
Exercise (hours/d)	2.0	(1.2, 2.6)	1.9	(1.5, 2.2)	1.5	(0.4, 2.5)
EI (MJ/d)	13.9	(11.5, 15.5)	15.5	(14.0, 19.2)	16.8	(14.2, 19.3)
EE_{SWA} (MJ/d)	20.9	(14.4, 22.1)	16.1	(15.0, 19.2)	13.4	(10.9, 16.0)
EI-EE_{SWA} (MJ/d)	-5.2	(-7.0, -3.2)[c]	-0.8	(-1.8, 0.7)	3.3	(3.3, 3.3)
EI:EE_{SWA} (MJ/d)	0.75	(0.67, 0.78)[d]	0.96	(0.88, 1.04)	1.25	(1.21, 1.30)

[a] UR were defined as having EI:EE_{SWA} of less than 0.80, AR in the range of 0.80-1.20 and OR greater than 1.20.
[b] P_{25} – 25th percentile, P_{75} – 75th percentile.
[c] $P < 0.001$ between UR and AR (Mann-Whitney test).
[d] $P < 0.001$ between UR and AR (Mann-Whitney test).

No significant differences were detected between UR and AR except from the difference between EI and EE_{SWA}, and the ratio of these two measurements.

When looking at only AR (n=24), the Pearson correlation coefficient between EI and EE_{SWA} was 0.86 ($P < 0.001$).

Comparison of macronutrient intake

Intake of protein, fat and carbohydrate among UR, AR and OR is presented in table 4.6. There were no significant differences in absolute intake or percentage of energy from macronutrients between UR and AR.

Table 4.6 Absolute intake of macronutrients and intake of macronutrients as percentage of energy estimated from the weighed diet record among under-reporters (UR), acceptable-reporters (AR) and over-reporters (OR)[a]

	UR (n=7)		AR (n=24)		OR (n=2)	
	Median	P_{25}, P_{75}[b]	Median	P_{25}, P_{75}	Median	P_{25}, P_{75}
Protein (g)	144	(119, 153)	155	(124, 173)	173	(130, 215)
Fat (g)	108	(103, 136)	136	(107, 155)	133	(88, 178)
Carbohydrate (g)	401	(357, 443)	479	(400, 651)	505	(494, 516)
Protein (% energy)	17.0	(16.0, 18.0)	16.0	(15.0, 17.0)	17.5	(16.0, 19.0)
Fat (% energy)	31.0	(28.0, 37.0)	30.0	(27.0, 35.8)	29.0	(23.0, 35.0)
Carbohydrate (% energy)	52.0	(45.0, 55.0)	54.0	(47.3, 57.8)	53.5	(46.0, 61.0)

[a] UR were defined as having EI:EE_{SWA} of less than 0.80, AR in the range of 0.80-1.20 and OR greater than 1.20.
[b]P_{25} – 25th percentile, P_{75} – 75th percentile.

Comparison of intake of selected foods and food groups

The intake of selected food items and food groups among UR, AR and OR are shown in table 4.7. The only significant result was that UR reported lower intake of bread than AR.

Table 4.7 Absolute intake of selected food items and food groups estimated from the weighed diet record among under-reporters (UR), acceptable-reporters (AR) and over-reporters (OR)[a]

	UR (n=7)		AR (n=24)		OR (n=2)	
	Median	P_{25}, P_{75}[b]	Median	P_{25}, P_{75}	Median	P_{25}, P_{75}
Fruit juice (g)	193	(0, 355)	319	(39, 397)	388	(140, 635)
Fruit and berries[c] (g)	108	(61, 169)	190	(142, 336)	145	(103, 186)
Vegetables[d] (g)	135	(20, 297)	157	(57, 198)	120	(47, 192)
5-a-day[e] (g)	544	(337, 611)	618	(472, 932)	652	(373, 930)
Bread (g)	194[f]	(177, 259)	298	(264, 349)	351	(331, 370)
Crisp bread (g)	0	(0, 12)	0	(0, 11)	9	(4, 13)
Breakfast cereals (g)	14	(0, 81)	63	(0, 132)	71	(0, 141)
Milk[g] (g)	382	(294, 886)	378	(166, 507)	455	(272, 637)
Chocolate and sweets (g)	13	(0, 42)	13	(0, 32)	31	(0, 61)
Carbonated soft drinks with sugar (g)	0	(0, 125)	25	(0, 134)	0	(0, 0)
Sports products[h] (g)	8	(0,15)	0	(0,13)	0	(0, 0)

[a] UR were defined as having EI:EE_{SWA} of less than 0.80, AR in the range of 0.80-1.20 and OR greater than 1.20.
[b] P_{25} – 25th percentile, P_{75} – 75th percentile.
[c] Only fresh fruit and berries.
[d] All vegetables except potatoes.
[e] 5-a-day calculated from fruit juice, fruit and berries and vegetables.
[f] $P = 0.007$ between UR and AR (Mann-Whitney test).
[g] Milk used as drink, in coffee or tea and on breakfast cereals.
[h] Supplements of carbohydrate and protein.

4.3 Comparison of energy expenditure estimated from the four-day physical activity record and energy expenditure measured with the SenseWear Pro_2 Armband

The values of EE_{SWA} and EE estimated from the four-day physical activity record (EE_{record}) are shown in table 4.8. The group average EE estimated from the activity record was significantly lower (-2.3 MJ/d) than the EE measured by SWA.

Table 4.8 Energy expenditure measured with the SenseWear Pro_2 Armband (EE_{SWA}) and estimated from the activity record (EE_{record}) and the relationship between EE from the two methods

	Total (n=33)		
	Mean	Median	SD[a]
EE_{SWA} (MJ/d)	17.1	16.1	3.1
EE_{record} (MJ/d)	14.9	14.7	2.0
EE_{record}-EE_{SWA} (MJ/d)	-2.3[b]	-2.3	1.7
EE_{record}:EE_{SWA} (MJ/d)	0.88	0.86	0.09

[a]Standard deviation.
[b] $P < 0.001$.

A Bland-Altman plot, showing the difference between EE estimated from the activity record and EE measured with SWA plotted against the mean of the two methods, is presented in figure 4.4. The plot illustrates that both under-reporting and over-reporting of EE occurred. The 95% CL of agreement varied from -5.7 to 1.2 MJ/d (± 2 SD), which indicates wide discrepancies between the two methods for individual subjects. The plot indicates that differences tended to increase as absolute EE increased.

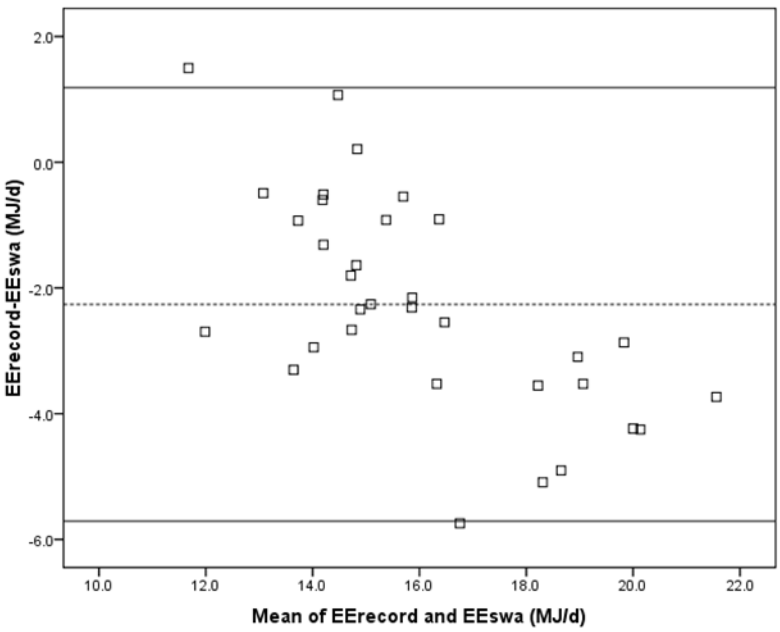

Figure 4.4 The difference between energy expenditure estimated from the activity record (EE_{record}) and energy expenditure measured with the SenseWear Pro_2 Armband (EE_{SWA}) plotted against the mean of the two methods. (·····), mean difference between the two methods; (—), SD 2 limits of agreement

The Pearson correlation coefficient between estimated and measured EE was 0.86 ($P < 0.001$). Figure 4.5 shows the association between the two methods for assessing EE.

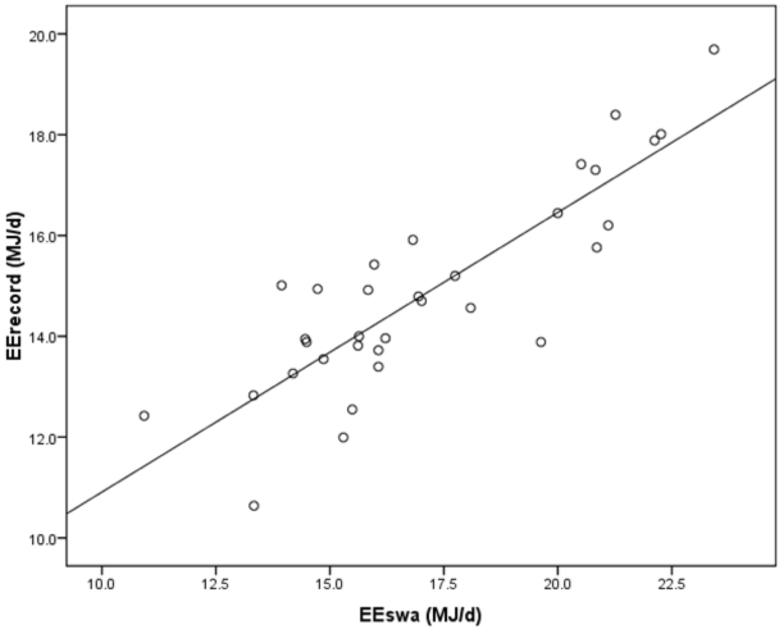

Figure 4.5 Energy expenditure estimated from the activity record (EE_{record}) plotted against energy expenditure measured with the SenseWear Pro_2 Armband (EE_{SWA}). (—), linear regression line

Twenty-two athletes (67%) appeared in the same third with both the activity record and SWA. No participants were grossly misclassified (table 4.9).

Table 4.9 Distribution of participants in thirds with regard to energy expenditure estimated from the activity record (EE_{record}) and measured by the SenseWear Pro_2 Armband (EE_{SWA})

		Thirds EE_{SWA}			
		1	2	3	Total
Thirds EE_{record}	1	**7**[a]	3	0	10
	2	4	**6**	2	12
	3	0	2	**9**	11
	Total	11	11	11	33

[a] The number of persons classified into the same third for both EE_{record} and EE_{SWA} is outlined with bolded font.

5. Discussion

The main purpose of the present study was to evaluate whether a four-day weighed diet record provides a valid measure of true EI of elite endurance athletes. Additionally we wanted to investigate whether a four-day physical activity record can give a reasonable estimate of an athlete's EE. As a reference method the activity monitor SenseWear Pro_2 Armband was used.

The results showed that the diet record and the activity record significantly under-estimated EI and EE respectively. However both methods were good in ranking individuals according to EI and EE.

The following section presents a discussion of the results and limitations of the study.

5.1 Sample

5.1.1 Participation rate

The participation rate in the present study was 49%. This is somewhat lower than reported by Helle (87) in a study of Norwegian top-level endurance athletes and by Burke et al. (88) in a study of Australian Olympic team athletes. The participation rate in both these studies were 58%, however, both males and females were included. In our study, only male athletes were invited to participate. Additionally, validation studies of dietary assessment methods generally involve a greater workload for the participants than general dietary surveys, and it may be more difficult to recruit participants (29;89).

The high participation rate among rowers (89%) observed in our study may be due to the close connection between one of the project co-workers and this sports community. The low participation rate among cyclist (22%) could be caused by a lot of travelling and staying abroad for these athletes, even in the training season.

Furthermore, the focus on nutrition among cyclists is high and they may already be satisfied with their diets and did not see any benefits of participating in the study.

To facilitate the recruitment, participants were promised a written evaluation of their diet and the results from their EE-measurements with SWA (appendix 7). Moreover, they were offered a measurement of body composition with dual energy X-ray absorptiometry (DXA) and a blood sample to check their blood levels of iron. These measurements were voluntary and not a mandatory part of the study. Those who where interested were invited to make an appointment with the investigator to go through all the results and to get a more sport specific nutrition guidance. Additionally, all participants were rewarded with a cook book for athletes. The use of a reward has been shown to enhance the participation rate in dietary surveys (90). Also, the fact that Olympiatoppen is central in Norwegian top-level sports and that this study was conducted in the regime of Olympiatoppen, may have contributed to a positive attitude towards participation.

The hectic life of an elite athlete with a lot of travelling may have been a general cause for not participating in this study. The recording preferably had to be performed in Norway and at the athlete's place of residence, which means that the athlete had to stay at home for four consecutive days including one Saturday or Sunday. This was not possible for all the potential participants. Furthermore, due to time pressure and different demands in everyday life, elite athletes are often encouraged to reduce activities which are not related to training and competition. The diet- and activity registration may have been considered as too demanding.

5.1.2 The representativity of the sample

In this study, only national team athletes from summer sports were included. The reason for this is because these athletes were in their training season at the time of data collection. In the training season there is less travelling and more stability in an athlete's life and it was assumed that the recording would be easier to perform in this period compared to in the competition season. It is more challenging to recruit athletes in the competition season when they are constantly on the move.

On the other side, by including winter sports the representativity of the sample of Norwegian elite athletes in endurance sports would have been improved. Swimming had to be excluded since the SWA can not be used in water, and thus we would not be able to get a representative measure of these athletes' EE.

The sample size could have been increased if we had included other athletes than only members of national teams. However, the intention of this study was to validate a dietary survey method used on athletes on the highest performance level, which is a unique group in sports nutrition science.

To limit the scope of this thesis, only male athletes were invited to participate. In view of the fact that fewer dietary surveys have been conducted on males, it was interesting to choose this group instead of females, although ideally both sexes should have been included. Viewed in the light of all these factors, the results from the present study can not with certainty be generalized to the entire population of Norwegian elite endurance athletes.

5.2 The reference method

It is important that the reference method gives a valid measure of what it is designed to measure. In this study it was an aim that the reference method would give a valid measure of EE at both the individual level and the group level. However, as there are reported varying amounts of error associated with SWA measurements it can not be considered as a "gold standard" for measuring EE. The validity of SWA is discussed below.

5.2.1 The validity of SenseWear Pro_2 Armband

SWA has been validated in children, obese and normal weight adults and in cancer and cardiac patients during the past five years (58-70). Only one of the studies have been looking at the ability of SWA to assess total daily EE in healthy adults and are thus the most relevant for this study (64).

St-Onge and colleagues (64) found that SWA under-estimated total daily EE by on average 117 kcal/d compared to DLW in a group of 45 normal weight subjects, including some diabetic (n=6). Although there was a significant group mean difference, individual values from the two methods were relatively similar as evidenced by an intraclass correlation (ICC) of 0.81. Furthermore, in a Bland-Altman plot, 80% of the values were within the predefined level of agreement between the methods (±300 kcal/d). The authors concluded that despite the tendency of SWA to under-estimate daily EE, there seems to be a reasonable concordance between SWA and DLW for measuring TEE.

Other studies have examined the validity of the SWA in estimating EE of adults at rest and during different modes of exercise in a laboratory setting (58-60;62;65;67;69). In the study by Fruin and Rankin (58) (n=13) and by Malavolti et al. (65) (n=99), no significant differences were found between mean REE measured by SWA and IC in a group of healthy, normal weight adults. Furthermore, the agreement as illustrated in a Bland-Altman plot and by a correlation coefficient was found to be good in both studies. Bertoli et al. (67) on the other hand, reported poor agreement between mean REE measured with SWA and IC (n=167). However, the participants in this study were overweight.

In the study by Fruin and Rankin (58) the SWA generated similar mean estimates of EE as IC on cycle ergometry (n=13). However, a poor correlation and a wide range of agreement in Bland-Altman analyses indicated that SWA is inappropriate for individual estimates of cycling exercises. When the participants walked on a horizontal surface at a treadmill (n=20), SWA significantly overestimated EE (by 14-

38 %), whereas it under-estimated the energy cost of walking on a 5% grade (by 22%). It needs to be mentioned that in this study, specific contextual algorithms were applied to the data by the manufacturer.

In the study by Papazoglou et al. (62), SWA underestimated REE by 8.8% (n=142) and highly overestimated EE during cycle ergometer (n=25), stepping (n=26) and treadmill walking exercise (n=20) in obese individuals, compared to EE measured with IC. However, in a control group of lean and overweight subjects (n=25), the two methods showed a high correlation ($r = 0.96$, $P < 0.001$) and a very good agreement, as illustrated by a Bland-Altman plot.

Jakicic et al (59) found that SWA underestimated EE at treadmill walk, cycle ergometry and stepping and overestimated EE at arm ergometry in a group of 40 normal weight subjects. Nevertheless, when they replaced the generalized equation that the software uses for calculating EE, with an exercise-specific equation, no significant differences between any of the exercises appeared.

In a recently study by Berntsen and his work group (69) they compared EE recorded from four different activity monitors, including SWA, with EE measured with IC. The participants (n=20) wore the monitors and a portable oxygen analyzer for 120 minutes while performing a variety of activities of different intensities. The findings of this study were that SWA significantly overestimated EE in moderate intensity physical activity ($P = 0.02$) and underestimated very vigorous intensity physical activity ($P < 0.001$). Furthermore, TEE recorded with SWA was under-estimated by on average 9% compared to IC during the 120 minutes of activity. Of the four activity monitors tested, SWA was one of two monitors that showed the best agreement with the reference method in measuring TEE. This is in accordance with another comparison of different activity monitors conducted by King et al. (60), who found SWA to give the best estimate of TEE during bouts of walking and running.

The results from the validation studies of SWA are somewhat ambiguous, and the use of different versions of both the armband and the software, and the application of specific algorithms in some cases, makes it difficult to compare the existing studies. To summarize, there seems to be an acceptable agreement between SWA and the DLW- and IC-methods in measuring mean TEE in normal weight adults. There also seems to be a promising concordance at the individual level. However, many of the studies presented above suffer from low sample sizes, and further research is needed before SWA can be considered a good method for measuring EE. Furthermore, no one has so far validated the use of SWA among elite endurance athletes, and whether this device provides an acceptable estimate of EE in this population, remains to be investigated.

The assumption that SWA generates valid measurements of EE at both the individual level and the group level is a major limitation of this study. Preferably, the methods validated in this study should have been compared with the DLW-method, which is regarded as the gold standard for measuring free-living EE. Considering the need of laboratory facilities as well as the costs of this method, it was not feasible for a master thesis. Due to the increasing interest in the use of SWA, it was tempting to test its use among athletes. SWA may represent a new, simple tool for assessing EE of athletes in the sports nutrition practice. However to confirm or disprove this, future studies to validate TEE measured with SWA in highly active populations are needed.

5.3 The test methods

5.3.1 The validity of the four-day weighed diet record

The development of the four-day weighed diet record presented in this study is based on the fact that diet records over three to four days are the most widely used method for dietary assessment of athletes (2). It is assumed that weighed records give more precise data for EI than estimated records (20;25;91). Therefore, a four-day weighed diet record is the preferable method to assess the EI and dietary patterns of elite athletes at Olympiatoppen.

In this study we found that mean self-reported EI was significantly lower than EE as determined by the SWA-method. This finding is consistent with investigations of other athletic populations where self-reported EI has been compared with EE from the DLW-method (14).

To date, there are only three studies where self-reported EI from a four-day weighed diet record has been validated against measured EE in athletes (4;13;15). One of the studies included men. In the study by Sjödin and co-workers (4), eight Swedish elite cross-country skiers participated, of whom four females and four males. Females weighed their diet for five days and males for four days. The results showed that there was a good agreement between EI and EE measured by DLW, with a mean difference (SD) for the entire group of only 0.1 (1.9) MJ/d. Furthermore, they found a very high correlation between EI and EE ($r = 0.96$, $P < 0.001$). This is the only study showing such a good agreement between self-reported EI and measured EE in elite endurance athletes with a high energy turnover.

Hill and Davies have investigated the energy balance in female classical ballet dancers (n=12) (13) and elite lightweight female rowers (n=7) (15). They found in both cases an under-reporting of EI of on average 21% (667 kcal/d) and 34% (1133 kcal/d) respectively, compared to EE measured with DLW. In our study, we revealed an under-reporting of 7.6% (311 kcal/d or 1.3 MJ/d), which is substantially lower than previously reported by Hill and Davies for female athletes (13;15). Burke has suggested that under-reporting may be less extensive among male elite athletes compared to their female counterparts (2). However, considering that SWA under-estimates TEE compared to DLW, as indicated by the studies discussed in the previous section, the discrepancy between EI and EE may be even larger and consequently the under-reporting may be of a greater extent than what is revealed with SWA in the present study.

Several authors have suggested that a correlation coefficient above 0.5 between two methods is good or satisfactory, whereas 0.30-0.49 is fair, and below 0.30 is poor (92;93). The correlation coefficient between the four-day weighed diet record and

SWA in this study was 0.58, indicating a relatively strong relationship between the two methods. However, it is important to have in mind that this correlation is between the weighed diet record and the reference method SWA, and not necessarily the real EE. In the study by Sjödin and co-workers (4), where DLW was used as the reference method, a higher correlation coefficient were reported ($r = 0.96$, $P = 0.0001$).

In the investigation of the ability of the four-day weighed diet record and SWA to classify individuals equally, 19 athletes (58%) were classified into the same third for both EI and EE, and only 2 athletes (6%) were grossly misclassified. This indicates that despite a significant difference between EI and EE at the group level, and great variances for the individual as illustrated by the Bland-Altman plot, there is a certain relationship between EI and EE since more than half of the participants were classified into the same third.

5.3.2 The use of the EI:EE ratio

In this thesis we characterised mis-reporters of EI. Subjects were identified as UR, AR and OR from their ratio $EI:EE_{SWA}$, according to Black (94). Both Black (94) and Rasmussen et al. (95) have suggested methods for calculating the 95% CL of agreement between EI and EE, where the lower CL (cut-off) represents the value below which it is unlikely that the reported mean EI represents either habitual long term intake or a low intake obtained by chance.

The equations used for calculating the cut-off values, rely on a coefficient of variation (CV) for the methods used for measuring EI and EE. Since we were not able to procure the CV for neither EI of athletes nor EE measured with SWA, we could not use the equations proposed by Black (94) and Rasmussen et al. (95). Thus, the definitions of UR ($EI:EE_{SWA}<0.80$), AR ($EI:EE_{SWA}$ 0.80-1.20) and OR ($EI:EE_{SWA}>1.20$) used in this study is based on a hypothetical 95% CL of ±20%. Both Black (94) and Rasmussen et al. (95) used a 95% CL of ±24% in adult people, whereas ±20% (89;96) and ±16% (97) has been reported used in studies of children.

We are aware of that the 95% CL chosen here might be too strict with regard to both the CV of EI among athletes and the CV of SWA. However, the purpose was to investigate potential differences in the intake of macronutrients and selected food items among those who had the greatest misreporting of EI compared to acceptable reporters.

5.3.3 Possible reasons for under-estimation of energy intake

It is generally recognised that self-reports of food intake under-estimate energy- and nutrient intake. The discrepancy between reported EI and measured EE may be explained in part of changes in normal dietary patterns and/or under-reporting of food intake, which can be both conscious and subconscious (98). The individual feedback promised to the participants in this study may have contributed to an attempt to eat healthier than normal to impress the investigator and to get a positive feedback. However, it has previously been suggested by Sjödin et al. (4) that the risk of altered eating behaviours due to diet recording is minimized among elite athletes, because of a high motivation to constantly select food in order to enhance performance. Several of the participants in this study reported that they had a regular diet with minimal variation between weekdays and weekends, which supports this belief.

According to Burke and colleagues (2) reporting error will be minimized when athletes are motivated to receive a true assessment of their diet and where detailed instructions to enhance record-keeping skills have been undertaken. The athletes were given both practical and written instruction in the implementation of the diet record, and the benefit of doing an accurate record for the feedback was emphasized. The fact that athletes are familiar with keeping detailed exercise diaries may have contributed to accurate diet records for some athletes.

It should also be kept in mind that most endurance athletes have irregular training and eating programmes, and lots of eating occasions. The weighing of each food item and beverage at the time of consumption may not be convenient because of lack of time and patience (20). Athletes frequently eat while on the move, and it is easy to forget to bring the weighing scale or to actually weigh the food before consumption. There is a chance that some meals or snacks have been omitted from the record book due to this problem, and therefore introduced some bias towards under-estimation of food intake. In a study of adult non-athletic subjects by Livingstone et al. (98), participants pointed out that weighing of snacks was the most onerous and irritating aspect of the weighing procedure. Consequently, subjects admitted to have omitted some measurements of snacks.

Another concern related to the accuracy of food records is the length of the diet-monitoring period. The number of days needed to provide an estimate of usual intake of energy and nutrients varies between individuals and groups, and also for different nutrients (25). In general, group assessment requires considerably fewer days of data collection than individual assessment, and the same holds true for the estimation of macronutrient compared to micronutrient intake (99). Monitoring periods of seven days are often recommended to minimize the effect of day-to-day variations in food intake, especially when intake of individuals are being examined (20). The minimum requirement is considered to be three days for group level measurements (20;25).

For athletes, the number of recording days is a compromise between accuracy and compliance. When increasing the recording period, accuracy may suffer due to reduced compliance and altered eating behaviour to simplify the recording process (98). Besides, periods longer than three to four days of food recording have high drop-out rates (25). A recording for three to four days is therefore the method of choice, in order to favour good compliance and to minimize the burden for the subjects (24). However, athletes may not necessarily be in energy balance during a four-day period. As an example, one of the cyclists participating in our study was out cycling for five hours one day and had a total EE of 35 MJ that day. During the four-day monitoring period, he did not manage to compensate this energy output with food intake. If the diet recording period had lasted longer, the discrepancy between EI and EE might have been counterbalanced. The same could be true if the subjects had worn the SWA for more than four days.

5.3.4 Characteristics of under-reporters

In the present study seven athletes (21%) were defined as UR. UR did not differ in physical characteristics compared to AR. Although not significant, UR had a higher median EE than the AR-group. This finding is consistent with other studies showing a negative correlation between EE and EI; the higher the EE the lower the EI (12;17-20).

The only significant dietary difference observed between UR and AR was that the former group reported less consumption of bread. However, since the percentage of energy from carbohydrates did not differ between the groups, it seems likely that UR rely more on other dietary sources of carbohydrates than bread. Nevertheless, there might be differences between the groups that we were not able to detect due to the low number of subjects in each group.

5.3.5 The validity of the four-day physical activity record

Although highly advanced methods for measuring TEE such as the DLW-method are available, it is not always the most appropriate technique due to costs and time. In the sports nutrition practice there is need for inexpensive, time-saving and practical methods to obtain objective measures of EE and hence energy needs of individuals. As long as there is no single, inexpensive and simple method for the assessment of EE and physical activity, different non-ideal methods are commonly used. The activity diary is one such method.

Since Bouchard et al. (81) described the first and original method for activity recording in 1983, several studies have been conducted to evaluate both the original and modified versions of the activity record (50;74;82;83). There seems to be a general consensus that activity records provide an acceptable estimate of EE in populations with relatively sedentary lifestyles. However, among active populations and at the individual level there is limited accuracy (50;74;81;82).

Boulay and colleagues (50) compared estimations of daily EE from a physical activity journal and a HR-monitoring method in endurance athletes and controls. Daily EE-estimates from the two methods were similar in controls whereas the HR-monitoring method yielded significantly higher EE results than the activity record in athletes (17.0 (4.0) MJ/d vs. 13.1 (2.1) MJ/d (mean (SD)), $P < 0.05$). This is in concordance with our results, where the SWA EE-measurement yielded significantly higher EE than the four-day activity record (17.1 (3.1) MJ/d vs. 14.9 (2.0) MJ/d (mean (SD)), $P < 0.001$). These findings together indicate that the physical activity level of subjects may influence the accuracy of a physical activity record.

At the individual level, Bland-Altman plots from several studies have shown wide limits of agreement between EE estimated from activity records and EE measured by DLW (74;82;83). This was also true for the present study, with limits of agreement ranging from -5.7 to 1.2 MJ/d. However, the correlation coefficient of 0.86 and the good classification of individuals into same thirds observed in this study, indicate that the activity record may be a valuable tool for ranking individuals according to EE.

5.3.6 Possible reasons for under-estimation of energy expenditure

Boulay et al. (50) proposed two possible reasons for their observed under-estimation of EE with the activity record method in trained individuals. One explanation was that highly trained athletes might under-estimate the intensity of their daily activities. Another explanation was that athletes might be less conscientious in recording their activities.

The first explanation is less likely in this study due to several reasons. First of all, the majority of elite athletes nowadays use HR-monitoring to discriminate between different intensities of exercise based on their maximal HR. It is common to carefully register training in an exercise diary with detailed description of time spent in different intensity levels. Thus, elite athletes have reasonably good knowledge about their own physical exertion during training. The probability that they under-estimate the intensity of their activities is therefore reduced, at least in activities where HR is monitored. What is more likely, however, is that they under-estimate the time devoted to different activities. This is typically done if the record is not kept consecutively. The importance of regularly updating the activity record, instead of doing it at the end of the day, was emphasized. Nevertheless, some athletes turned out to have forgotten to register their activity for one or more days, and had to complete the record to the best of their ability at the last meeting with the investigator. Due to the difficulty of remembering the activities performed every 30-minute the previous days, this may have contributed to some bias.

Furthermore, the methodology used by Boulay et al. (50) and in the present study differs and can not be directly compared. In the former study they used the method proposed by Bouchard et al. (81), with each day divided into 96 periods of 15 minutes each and where the subject enters a digit from 1-9 representing the most dominant activity in each period. The digits from 1-9 represents 9 different activity categories with each having a predetermined average energy cost. This is the most used approach for activity records in literature. However, such a detailed recording comes at the cost of time commitments for both subject and investigator (27). In our experience, elite athletes do not manage to complete an activity record even for a few days if 15-minute or shorter periods are used. Therefore, 30-minute intervals were chosen in this study in an attempt to reduce the participant burden and improve the compliance. Furthermore, instead of entering a digit for the most dominant activity each 30-minute interval, the participants were asked to make a written description of activities and the associated degree of physical exertion. Afterwards, the investigator had to add an appropriate energy cost to each of the 48 periods a day was divided into (table 3.1). In contrast to the study by Boulay et al. (50), the bias towards under- or over-estimation of energy costs of activities therefore rely on the investigator more than the athletes themselves in the method used in the present study.

The suggestion that athletes may be less conscientious in recording their activities is a potential explanation for the under-estimation of EE observed in our study. Despite the thorough instruction given to all participants, some recorded their activities very precisely while others did not. Registration of diet, exercise and activity at the same time may have been too much work for the athletes in addition to their exercise diaries. The activity record may have been given a lower priority because of the simultaneously measurement of EE with SWA and knowing that the activity record was of little importance for the individual feedback.

Another source of error associated with the activity record is the coarse grouping of activities into categories and the choice of an average energy cost of each category. We based our classification of six activity categories and appurtenant energy costs on a table presented by Manore and Thompson (84), that is aimed for athletes (table 3.1). Compared to the compendium of physical activities developed by Ainsworth and colleagues (79), this classification seems reasonable.

However, there are other concerns regarding the activity record. Firstly, there is a wide range of activities and physical efforts not listed in the available reference lists, for instance spontaneous physical activity and fidgeting (77). Secondly, measured energy cost of different activities may be different than in real life due to the measuring procedure and the wearing of unfamiliar equipment while performing an activity (77). Perhaps most important, since the values of energy costs are averages, they do not take into account that some people perform activities more vigorously than others. Individual differences in EE can be large and the true energy cost for a person may or may not be close to the stated mean (79).

The use of the Harris-Benedict equation to calculate EE may have contributed to some under-estimation of actual BMR-values. Thompson and Manore (100) compared RMR values measured in the laboratory with RMR values predicted from six different equations in active males and females. They found that the Cunningham equation was the best predictor of RMR in this population. The Cunningham equation requires the measurement of lean body mass. Due to lack of this parameter we could not use this equation in our calculations. Instead we used the Harris-Benedict equation which was proved to be the next best predictor, with slightly lower values of RMR compared to laboratory measurements.

6. Conclusion

The results from the present study showed that average self-reported EI was significantly lower than EE measured with SWA. The mean difference was 1.3 MJ/d. At the individual level, a Bland-Altman plot illustrated a wide discrepancy between self-reported EI and measured EE. However, the correlation coefficient of 0.58 and the good classification of individuals into thirds indicated a high ability of the four-day weighed diet record in ranking individuals according to EI.

When comparing average estimated EE from the four-day physical activity record with SWA-measurements of EE, a significant mean difference of - 2.3 MJ/d were detected. A Bland-Altman plot illustrated great variation between the two methods for each individual. However, the activity record showed a high ability in ranking individuals according to EE, as evidenced by a correlation coefficient of 0.86 and the very good classification of individuals into thirds.

Seven athletes (21%) were classified as UR. The only significant difference in their reported diet compared to AR was a lower consumption of bread.

The findings from the present study indicate that the self-reported weighed diet record may represent an acceptable method for the quantification of EI of groups of athletes. At the individual level, there may be unacceptable levels of error associated with its use. Until a better method for quantifying EI of athletes is proved, the weighed diet record will continue to represent a useful method in the sports nutrition practice. However, the interpretation of its results of EI should be made with caution.

The activity record is an unsuitable tool for assessing EE of both individuals and groups of elite athletes. It may be a valuable tool for ranking individuals according to their EE and to investigate activity patterns, as activity records have the advantage of providing additional information on the types of activity and time devoted by individuals to specific activities.

In order to be able to give athletes correct nutritional recommendations, there is obviously need for an objective and practical tool to evaluate EI and energy needs. Future studies should aim at validating new, promising instruments, like the SWA, for objective assessment of EE in athletes. The SWA is simple in use and may represent a practical and accurate way of both assessing EE and hence energy needs of an athlete, and to evaluate self-reported EI.

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Appendixes

Appendix 1: Approvals from the National Committees for Research Ethics in Norway

UNIVERSITETET I OSLO
DET MEDISINSKE FAKULTET

Ernæringsfysiolog Christine Helle
Olympiatoppen, Norges idrettsforbund
og olympiske og paralympiske komité
Postboks 4004 Ullevål Stadion
0806 Oslo

Regional komité for medisinsk forskningsetikk
Sør-Øst- Norge B (REK Sør-Øst B)
Postboks 1130 Blindern
NO-0318 Oslo

Telefon: 228 50 663
Telefaks: 228 44 661
E-post: rek-sorost@medisin.uio.no
Nettadresse: www.etikkom.no

Dato: 22.06.2008
Deres ref.:
Vår ref.: S-08444b

S-08444b Validering av energiinntak målt med 4-dagers veid kostregistrering blant toppidrettsutøvere ved hjelp av energiforbruk målt med Sensewear Pro Armband

Komiteen behandlet søknaden i sitt møte den 12. juni 2008. Prosjektet er vurdert etter lov om behandling av etikk og redelighet i forskning av 30. juni 2006, jfr. Kunnskapsdepartementets forskrift av 8. juni 2007 og retningslinjer av 27. juni 2007 for de regionale komiteer for medisinsk og helsefaglig forskningsetikk.

Saksfremstilling
I dette masterprosjektet skal resultatene av kostregistrering og av aktivitetsregistrering sammenholdes med energibruk målt med Sensewear Proarmbånd under en 7-dagers periode.

Forskningsetisk vurdering
En validering av en vitenskapelig metode forutsetter en pålitelig referansemetode eller definert "fasit". I beskrivelsen av prosjektet i søknaden står det at både kostregistrering og energiregistrering (dagbok) skal valideres mot Sensewear-armbånd metoden. Selv om det åpenbart er en fornuftig tilnærming å bruke denne siste metoden som referansemetode, fremgår det imidlertid av protokollen at også denne metoden har klare feilkilder. Prosjektet ville derfor stå seg på å bruke begrepet validering mer restriktivt. Komiteen har ellers ingen forskningsetiske innvendinger mot at studien gjennomføres.

Komiteen har ingen merknader til informasjonsskriv/samtykkeerklæring.

Vedtak
Komiteen godkjenner at prosjektet gjennomføres i samsvar med det som framgår av søknaden.

Komiteens avgjørelse var enstemmig.

Med vennlig hilsen

Tor Norseth (sign.)
Leder

Jorunn Lindholt
Jorunn Lindholt
Fungerende komitésekretær

UNIVERSITETET I OSLO
DET MEDISINSKE FAKULTET

Ernæringsfysiolog Christine Helle
Olympiatoppen, Norges idrettsforbund
og olympiske og paralympiske komité
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Regional komité for medisinsk forskningsetikk
Sør-Øst- Norge B (REK Sør-Øst B)
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Telefon: 228 50 663
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E-post: juliannk@medisin.uio.no
Nettadresse: www.etikkom.no

Dato: 14.08.2008
Deres ref.:
Vår ref.: S-08444b 2008/13342

S-08444b Validering av energiinntak målt med 4-dagers veid kostregistrering blant toppidrettsutøvere ved hjelp av energiforbruk målt med Sensewear Pro Armband

Vi viser til skjema for protokolltillegg og endringer signert 05.08.08 med spørsmål om godkjenning av å gi deltakerne i studien tilbud om vurdering av jernstatus og kroppssammensetning. Vedlagt følger revidert informasjonsskriv.

Komiteen har ingen innvendinger til endringen i studien. Komiteen har ingen merknader til revidert informasjonsskriv.

Vi ønsker lykke til videre med studien!

Med vennlig hilsen

Tor Norseth (sign.)
Leder

Julianne Krohn-Hansen
komitésekretær

Appendix 2: Approval from Norwegian Social Science Data Services

Norsk samfunnsvitenskapelig datatjeneste AS
NORWEGIAN SOCIAL SCIENCE DATA SERVICES

NSD

Harald Hårfagres gate 29
N-5007 Bergen
Norway
Tel: +47-55 58 21 17
Fax: +47-55 58 96 50
nsd@nsd.uib.no
www.nsd.uib.no
Org.nr. 985 321 884

Lene Frost Andersen
Avdeling for ernæringsvitenskap
Institutt for medisinske basalfag
Universitetet i Oslo
Postboks 1046 Blindern
0316 OSLO

Vår dato: 10.10.2008 Vår ref: 19893 / 2 / KS Deres dato: Deres ref:

TILRÅDING AV BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 08.09.2008. Meldingen gjelder prosjektet:

19893	*Validering av energiinntak målt med 4-dagers veid kostregistrering blant toppidrettsutøvere ved hjelp av energiforbruk målt med Sensewear Pro Armband*
Behandlingsansvarlig	*Universitetet i Oslo, ved institusjonens øverste leder*
Daglig ansvarlig	*Lene Frost Andersen*
Student	*Marianne Udnæseth*

Personvernombudet har vurdert prosjektet, og finner at behandlingen av personopplysninger vil være regulert av § 7-27 i personopplysningsforskriften. Personvernombudet tilrår at prosjektet gjennomføres.

Personvernombudets tilråding forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, eventuelle kommentarer samt personopplysningsloven/-helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/forsk_stud/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://www.nsd.uib.no/personvern/prosjektoversikt.jsp.

Personvernombudet vil ved prosjektets avslutning, 30.06.2009, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Vigdis Namtvedt Kvalheim Katrine Utaaker Segadal

Kontaktperson: Katrine Utaaker Segadal tlf: 55 58 35 42
Vedlegg: Prosjektvurdering
Kopi: Marianne Udnæseth, Tønsberggata 3, 0464 OSLO

Appendix 3: Written invitation to participate in the study

Forespørsel om deltakelse i forskningsprosjektet

"Validering av energiinntak målt med 4-dagers veid kostregistrering blant toppidrettsutøvere ved hjelp av energiforbruk målt med SensWear Pro Armband"

Bakgrunn og hensikt
Dette er et spørsmål til deg om å delta i en studie i feltet idrettsernæring. Formålet med denne studien er å undersøke validiteten (kvaliteten) til 4-dagers veid kostregistrering, som er den mest brukte metoden for innhenting av individuelle kostholdsdata på toppidrettsutøvere. Valideringsstudien gjennomføres for å gi kunnskap om hvor god 4-dagers veid kostregistrering er til å måle det sanne inntak hos toppidrettsutøvere, samt å gi kunnskap om hvilken type feil som er knyttet til metoden. Dette er viktig for å kunne tolke resultater fra kostregistreringer, og for å kunne tolke sammenhengen mellom kosthold og idrettsprestasjon.

For å gjennomføre studien trenger vi 30-40 frivillige mannlige toppidrettsutøvere som driver med følgende utholdenhetsidretter: orientering, sykling, langdistanseløp, kappgang, roing og padling. De må være over 18 år, på et høyt prestasjonsnivå innen sin idrett, og være friske og skadefrie i registreringsperioden. Derfor henvender vi oss til deg.

Studien er en masteroppgave i klinisk ernæring ved Universitetet i Oslo, og utføres i samarbeid med Olympiatoppens ernæringsavdeling. Den skal ledes av masterstudent Marianne Udnæseth, med veiledning fra ernæringsfysiolog Cand.scient. Christine Helle fra Olympiatoppens ernæringsavdeling.

Hva må du gjøre når du deltar i studien?
Du må gjennomføre en 4-dagers veid kostregistrering, og en 4-dagers aktivitetsregistrering. Du vil få utdelt registreringsskjema og vekt, og vi gir deg god instruksjon i hvordan skjemaene skal fylles ut. I tillegg vil du få utdelt et "SenseWear Pro Armband" som skal bæres rundt armen i 4 dager for å registrere fysisk aktivitet. Ditt bidrag til studien vil altså være at du må sette av 4 sammenhengende dager i perioden september 2008-januar 2009, til registrering av kosthold og fysisk aktivitet.

Hva får du igjen for å delta?
Fordelen med å delta i denne studien er at du kan få en vurdering av kostholdet ditt og se om du imøtekommer kostholdsanbefalingene for din idrett. I tillegg får du målt energiforbruket ditt. Vi vil også tilby alle som deltar i studien en vurdering av jernstatus og kroppssammensetning. Hvis du ønsker, får du time hos ernæringsfysiolog hvor alle resultater blir gjennomgått sammen med deg. Eventuelt kan du få skriftlig tilbakemelding i posten. Som takk for deltakelsen vil du motta kokeboken "Overskudd – kokebok for deg som trener", skrevet av Christine Helle.

Ulempen med å delta, er at det kan være tidkrevende å veie all mat du spiser og registrere hva slags aktiviteter du utfører i løpet av dagen, men de fleste synes det går greit etter en dags "innkjøring".

Hva skjer med informasjonen om deg?
Informasjonen som registreres om deg, skal kun brukes slik som beskrevet i hensikten med studien. Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger. Det er bare en kode som knytter deg til dine resultater. Det er kun autorisert personell knyttet til prosjektet som har adgang til navnelisten, og som kan finne tilbake til deg. Andre personer kan dermed ikke se dine resultater, og det vil ikke være mulig å identifisere deg i resultatene av studien når disse publiseres. Prosjektet er godkjent av Regionale komiteer for medisinsk og helsefaglig forskningsetikk og meldt til Norsk samfunnsvitenskapelig datatjeneste.

Frivillig deltakelse
Det er frivillig å delta i studien. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke til å delta i studien. Du kan også trekke deg underveis i studien hvis du av en eller annen grunn ikke ønsker å fullføre.

Dersom du ønsker å delta, ber vi deg undertegne den vedlagte samtykkeerklæringen og sende den til oss så raskt som mulig, helst innen tirsdag 30. september. Bruk vedlagte frankerte konvolutt. Når vi har mottatt ditt samtykke, kontakter vi deg per telefon for å avtale videre forløp. Om du nå sier ja til å delta, kan du senere trekke tilbake ditt samtykke.

Dersom du har spørsmål til studien, kan du kontakte Marianne Udnæseth på telefon 917 72 858.

Vennlig hilsen

Marianne Udnæseth
Masterstudent i klinisk ernæring
Universitetet i Oslo

Christine Helle
Ernæringsfysiolog
Olympiatoppen

Postadresse:
Olympiatoppen
Postboks 4004 Ullevål Stadion
0806 Oslo

Samtykke til deltakelse i studien

Jeg er villig til å delta i studien

Navn: ………………………………………………..

Adresse: ………………………………………………..

………………………………………………..

………………………………………………..

Telefon: ………………………………………………..

---------------------- --

Dato Signert av prosjektdeltaker

Jeg bekrefter å ha gitt informasjon om studien

---------------------- --

Dato Signert av prosjektmedarbeider, rolle i studien

Appendix 4: The record notebook

OLYMPIATOPPEN

4 dagers kost- og aktivitetsregistrering for toppidrettsutøvere

Validering av energiinntak målt med 4-dagers veid kostregistrering blant toppidrettsutøvere ved hjelp av energiforbruk målt med Sensewear Pro Armband

Navn: ……………………………………………………………………………

Adresse: ……………………………………………………………………………

Telefon: ……………………………………………………………………………

E-mail: ……………………………………………………………………………

Idrett: ……………………………………………………………………………

Dato (fra-til): ……………………………………………………………………………

Veiledning for kostregistrering (gule ark)

- Du skal registrere kostholdet ditt i 4 dager (3 ukedager + 1 lørdag eller søndag)
- Du skal også registrere treningen og aktivitetsnivået ditt i de samme 4 dagene
- Prøv å unngå at kostregistreringen forandrer matvanene dine - **spis slik du vanligvis gjør**!
- Skriv ned alt du spiser og drikker, også evt. kosttilskudd
- Skriv ned evt. væskeinntak og matinntak under trening på sidene for treningsregistreringen
- Start med det første måltidet den dagen registreringen begynner. Fyll inn alle måltidene du spiser, både hoved- og mellommåltider. For hvert måltid skal følgende skrives ned (se også eksempel på 1-dags kostregistrering på neste side):

1) Klokkeslett
2) Navnet på matvaren eller retten → gi flest mulig opplysninger

- f.eks Birkebeinerbrød, Norvegia hvitost, Nora jordbærsyltetøy, lett melk, 15 kr Freia melkesjokolade
- evt. oppskrift på hjemmelagete retter (skriv oppskriften bak på arket)
- evt. hvordan retten er tilberedt (kokt, stekt etc.)

NB! Jo flere opplysninger du gir, jo riktigere blir beregningene. Se på matvareemballasjen når du skal notere navnet. Hvis det er spesielle matvarer, kan du ta vare på emballasjen og legge den med.

3) Mengde av matvaren eller retten

→ oppgi mengde i gram når du har vekt tilgjengelig
→ oppgi mengde i husholdningsmål når du ikke har vekt
- antall, stykker, spiseskje, teskje, glass, kopp, dl

Veiing

- Brødskiver: Nullstill vekten. Sett asjetten på vekten. Nullstill. Legg på brødskiven, les av og noter hva den veier. Nullstill. Smør på brødskiven, legg den på vekten igjen, les og noter. Nullstill. Legg på pålegg, les av og noter.
- Kornblanding: Sett tallerkenen på vekten. Nullstill. Ha i kornblandingen, les av og noter vekten. Nullstill. Ha i melk/yoghurt etc., les av og noter vekten.
- Middag: Vei når retten er ferdig tilberedt (etter at maten er kokt, stekt etc.) Sett tallerken på vekta. Nullstill. Vei så en og en ting om gangen. Les av og noter vekten, og nullstill mellom hver gang du legger på noe nytt.
- Sammenkokte retter: Veies i ett (f.eks fiskegrateng, gryterett o.l).

NB!

- Vekten veier ikke mengder på 2 g eller mindre. Noter alle matvarer selv om de ikke gir noe utslag på vekta, slik som f.eks. minimalt med margarin på brødskiva, en agurkskive til pynt etc.
- Bein (f.eks. på kotelett), skinn (f.eks. på fiskeskiver), skall (f.eks. på banan) og annet som ikke er spiselig, veies for seg etterpå og trekkes fra vekten på den totale matvaren. Du kan evt. fjerne det før du veier. Hvis du ikke har anledning til å veie det før eller etter, husk alltid å notere at vekten på matvaren inkluderer skall, bein etc.

Veiledning for treningsregistrering (grønne ark)

Her skal du registrere de treningsøktene du har i løpet av en dag. Skriv ned type trening, intensitet (sone) og varighet på økta. I tillegg skal du registrere det du eventuelt inntar av væske og mat under økta. Beskriv type og oppgi mengde i ml/g. Hvis du ikke har vekt tilgjengelig, oppgi mengde i husholdningsmål (f.eks. 2 måleskjeer Maxim energidrikk i 750 ml vann, 1 banan etc.).

Veiledning for aktivitetsregistrering (hvite ark)

Her skal du registrere aktivitetsnivået ditt i løpet av døgnet. Fyll inn hva du gjør hvert 30 min i løpet av døgnet: for eksempel *sove, dusje, kle på deg, lage mat, spise, kjøre bil, gå til buss, sitte på buss, sitte på jobb/skole, handle, gå tur etc*. På de timene/minuttene du skriver *trening*, må du beskrive type trening og intensitet: for eksempel oppvarming løp/sykkel, utholdenhetstrening langdistanse, styrketrening 30 reps, styrketrening max, rolig teknikktrening etc. (du kan bruke de samme opplysningene som du har skrevet på treningsregistreringen).

SKRIV TYDELIG!

Ring eller mail meg hvis du har noen spørsmål: *917 72 858*
marianne.udnaseth@studmed.uio.no

Registreringen skal leveres sammen med monitoren og tilhørende skjema umiddelbart etter at du er ferdig.

Lykke til!

Marianne Udnæseth
Masterstudent i klinisk ernæring
Universitetet i Oslo

KOSTREGISTRERING (eksempel) **Dag 1**

Måltid 1 Kl. 07.00

Matvarer/retter	Mengde
Grovt rugbrød, kjøpt	82 g
Soft flora margarin	10 g
Leverpostei (Gilde go' og mager) + agurk	21 g + 13 g
Nora jordbærsyltetøy	28 g
Lettmelk	150 g
Appelsinjuice	150 g

Måltid 2 Kl. 10.00

Matvarer/retter	Mengde
Go'morgen yoghurt	195 g
Te	200 g
Lettmelk i teen	10 g

Måltid 3 Kl. 12.30

Matvarer/retter	Mengde
Grillet kyllingkjøtt	150 g
Isbergsalat + mais + agurk + tomat	28 g + 23 g + 19 g + 65 g
Fransk dressing	17 g
Halvstekt grov baguett	120 g
Soft flora margarin	10 g
Vann	500 g

Måltid 4 Kl. 14.00

Matvarer/retter	Mengde
Eple	164 g

Måltid 5 Kl. 17.00

Matvarer/retter	Mengde
Kokt torsk	200 g
Kokt potet	167 g
Kokt gulrot	123 g
Smeltet margarin	11 g
Vann	300 g

Måltid 6 Kl. 20.00

Matvarer/retter	Mengde
Axa Go dag Frukt, komblanding	83 g
Lettmelk	200 g
Banan	110 g

KOSTREGISTRERING **Dag 1**

Måltid 1 Kl. ..…………..

Matvarer/retter	Mengde
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TRENINGSREGISTRERING **Dag 1**

NB! Skriv ned væskeinntak og matinntak (mengde og type) hvis du bruker det *under* *trening*

Økt 1 Kl. ………..……..

Type trening og intensitet Varighet

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Type væske-mat inntak *Mengde*

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Økt 2 Kl. ………..……..

Type trening og intensitet Varighet

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Type trening og intensitet Varighet

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Type væske-mat inntak *Mengde*

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Evt. kommentarer til kostregistrering/treningsregistrering:

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AKTIVITETSREGISTRERING **Dag 1**

Her skal du registrere aktivitetsnivået ditt i løpet av døgnet. Fyll inn hva du gjør hvert 30 min i løpet av døgnet: for eksempel *sove, dusje, kle på deg, lage mat, spise, kjøre bil, gå til buss, sitte på buss, sitte på jobb/skole, handle, gå tur etc*. På de timene/minuttene du skriver *trening*, må du beskrive type trening og intensitet: for eksempel oppvarming løp/sykkel, utholdenhetstrening langdistanse, styrketrening 30 reps, styrketrening max, rolig teknikktrening etc. (du kan bruke de samme opplysningene som du har skrevet på treningsregistreringen).

Klokkeslett	Type aktivitet - hva du gjør i hvert tidsrom
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KOSTREGISTRERING **Dag 2**

Måltid 1 Kl. ..………..

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Matvarer/retter Mengde

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TRENINGSREGISTRERING **Dag 2**

NB! Skriv ned væskeinntak og matinntak (mengde og type) hvis du bruker det under trening

Økt 1 Kl. ………..……..

Type trening og intensitet Varighet

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Type væske-mat inntak *Mengde*

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Evt. kommentarer til kostregistrering/treningsregistrering:

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AKTIVITETSREGISTRERING **Dag 2**

Her skal du registrere aktivitetsnivået ditt i løpet av døgnet. Fyll inn hva du gjør hvert 30 min i løpet av døgnet: for eksempel *sove, dusje, kle på deg, lage mat, spise, kjøre bil, gå til buss, sitte på buss, sitte på jobb/skole, handle, gå tur etc*. På de timene/minuttene du skriver *trening*, må du beskrive type trening og intensitet: for eksempel oppvarming løp/sykkel, utholdenhetstrening langdistanse, styrketrening 30 reps, styrketrening max, rolig teknikktrening etc. (du kan bruke de samme opplysningene som du har skrevet på treningsregistreringen).

Klokkeslett	Type aktivitet - hva du gjør i hvert tidsrom
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KOSTREGISTRERING **Dag 3**

Måltid 1 Kl. ..………..

Matvarer/retter Mengde

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Måltid 4 Kl. …………..

Matvarer/retter Mengde

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TRENINGSREGISTRERING **Dag 3**

NB! Skriv ned væskeinntak og matinntak (mengde og type) hvis du bruker det under trening

Økt 1 Kl. ………..……..

Type trening og intensitet Varighet

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Type væske-mat inntak *Mengde*

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Type væske-mat inntak *Mengde*

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Evt. kommentarer til kostregistrering/treningsregistrering:

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AKTIVITETSREGISTRERING **Dag 3**

Her skal du registrere aktivitetsnivået ditt i løpet av døgnet. Fyll inn hva du gjør hvert 30 min i løpet av døgnet: for eksempel *sove, dusje, kle på deg, lage mat, spise, kjøre bil, gå til buss, sitte på buss, sitte på jobb/skole, handle, gå tur etc*. På de timene/minuttene du skriver *trening*, må du beskrive type trening og intensitet: for eksempel oppvarming løp/sykkel, utholdenhetstrening langdistanse, styrketrening 30 reps, styrketrening max, rolig teknikktrening etc. (du kan bruke de samme opplysningene som du har skrevet på treningsregistreringen).

Klokkeslett	**Type aktivitet - hva du gjør i hvert tidsrom**
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KOSTREGISTRERING **Dag 4**

Måltid 1 Kl. ..………..

Matvarer/retter Mengde

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Matvarer/retter Mengde

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Måltid 4 Kl. …………..

Matvarer/retter Mengde

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Måltid 5 Kl. …………..

Matvarer/retter Mengde

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Måltid 6 Kl. …………..

Matvarer/retter Mengde

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TRENINGSREGISTRERING **Dag 4**

NB! Skriv ned væskeinntak og matinntak (mengde og type) hvis du bruker det under trening

Økt 1 Kl. ………..……..

Type trening og intensitet Varighet

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Type væske-mat inntak *Mengde*

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Økt 2 Kl. ………..……..

Type trening og intensitet Varighet

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Type trening og intensitet Varighet

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Type væske-mat inntak *Mengde*

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Evt. kommentarer til kostregistrering/treningsregistrering:

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AKTIVITETSREGISTRERING **Dag 4**

Her skal du registrere aktivitetsnivået ditt i løpet av døgnet. Fyll inn hva du gjør hvert 30 min i løpet av døgnet: for eksempel *sove, dusje, kle på deg, lage mat, spise, kjøre bil, gå til buss, sitte på buss, sitte på jobb/skole, handle, gå tur etc*. På de timene/minuttene du skriver *trening*, må du beskrive type trening og intensitet: for eksempel oppvarming løp/sykkel, utholdenhetstrening langdistanse, styrketrening 30 reps, styrketrening max, rolig teknikktrening etc. (du kan bruke de samme opplysningene som du har skrevet på treningsregistreringen).

Klokkeslett	**Type aktivitet - hva du gjør i hvert tidsrom**
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24.30-01.00	

Appendix 5: Written information about the SenseWear Pro_2 Armband given to the participants

Informasjon om aktivitetsmonitoren Armband

ID-nr (person)	
Armband-nr	

Bruk

- Monitoren skal alltid sitte på høyre overarm, med den minste grå sirkelen pekende oppover (se bildet).
- Monitoren skal tas av ved dusjing og bading, men ellers være påmontert hele tiden, også når du sover.
- Ikke stram båndet for hardt, det skal ikke være ubehagelig stramt.
- Det er lett at monitoren sklir ned når du f.eks tar av genseren. I så fall flytter du monitoren tilbake i riktig posisjon på armen.
- Du trenger ikke trykke på noe for å starte monitoren, den starter av seg selv når du setter den på armen (og slutter å måle når du tar den av).
- Når du setter monitoren på armen vil du som regel etter en stund høre en summelyd og vibrering – dette er normalt. Tilsvarende hører man vanligvis et lydsignal når du tar av monitoren. Innimellom kan monitoren også avgi lyd/vibrasjon mens du har den på armen. Dette er også normalt.
- Ikke trykk på knappen på monitoren eller ta opp lokket.
- Ikke lån bort monitoren til andre, det er kun du som skal benytte monitoren.

Tidsrom for din måling

Start måling (klokkeslett/dato):		
Avslutt måling (klokkeslett/dato):		

Innleveringsrutiner

Monitoren skal leveres til oss umiddelbart etter at måleperioden er ferdig. Dette avtaler vi når du starter forsøket. NB! DETTE ER MEGET VIKTIG DA MONITOREN SKAL BENYTTES AV ANDRE FORSØKSPERSONER RETT ETTERPÅ.

Vennligst svar på spørsmålene på baksiden på dette arket, og lever det sammen med monitoren.

Vennligst besvar følgende spørsmål

1. Har monitoren vært behagelig å gå med? (ett kryss)

☐ Svært behagelig
☐ Ganske behagelig
☐ Noe ubehagelig
☐ Svært ubehagelig

Hvis monitoren har vært svært eller noe ubehagelig å gå med – hva skyldes dette?

____

____

2. Har du hatt monitoren på armen stort sett hele tiden i disse 4 dagene? (ett kryss)
☐ Nei, jeg har hatt monitoren på armen i liten eller ingen grad
☐ Det er en eller flere dager, eller lengre perioder, jeg ikke har hatt monitoren på armen
☐ Jeg har stort sett hatt monitoren på armen, men tatt den av ved enkelte anledninger/kortere perioder
☐ Jeg har hatt monitoren på armen tilnærmet hele tiden, unntatt ved dusjing/bading

Hvis du i lange perioder ikke har hatt monitoren på armen – hva skyldes dette?

____

____

3. Har du hatt monitoren på armen de samme 4 dagene som du har gjort veid kostregistrering?
☐ Ja
☐ Nei

Hvis nei – hva skyldes dette?

____

____

4. Ønsker du time hos ernæringsfysiolog for å få en vurdering av ditt kosthold, jernstatus og kroppssammensetning, samt resultater fra målingen av din fysiske aktivitet (monitor-data)?
☐ Ja
☐ Nei
☐ Ønsker kun å få resultatene tilsendt i posten

Ved spørsmål rundt bruken av Armband, ta kontakt med Marianne: marianne.udnaseth@studmed.uio.
917 72 858

TAKK FOR DIN DELTAGELSE OG INNSATS I PROSJEKTET!

Appendix 6: Control questions to the diet- and activity record

Kontrollspørsmål til kost- og aktivitetsregistrering

ID:

1) Har du i perioden du har registrert kostholdet hatt et "vanlig" kosthold?
☐ Ja ☐ Nei

Hvis nei, hva er endret i forhold til det kostholdet du vanligvis har?
- spist mer enn vanlig ☐
- spist mindre enn vanlig ☐
- spist flere måltider pr dag ☐
- spist færre måltider pr dag ☐
- mer bevisst i forhold til valg av matvarer ☐
- mindre bevisst i forhold til valg av matvarer ☐
- gjennomført et spesielt kostregime ☐
  hvilket ....
- annet ....

2) Har du endret kroppsvekt i perioden du har registrert kostholdet?
☐ Ja ☐ Nei

Hvis ja, har du
- gått opp i vekt ☐
- gått ned i vekt ☐

Hvis ja, hvorfor har du endret kroppsvekt?
- bevisst ☐
- sykdom ☐
- treningsbelastning ☐
- annet ....

Hvis ja, har dette påvirket kostholdet ditt de dagene du har registrert kostholdet?
- spist mer ☐
- spist mindre ☐
- annet ....

4) Har du vært syk i perioden du har registrert kostholdet?
☐ Ja ☐ Nei

Hvis ja, hvordan syk har du vært
- forkjølt/influensa ☐ ant. dager ☐
- feber ☐ ant. dager ☐
- omgangssyke ☐ ant. dager ☐
- mage/tarm problem ☐ ant. dager ☐
- annet .... ☐ ant. dager ☐

5) Har du brukt medisiner i perioden du har registrert kostholdet?
☐ Ja ☐ Nei

Hvis ja, hvilke
....
....

Bruk av kosttilskudd

6) Bruker du kosttilskudd?

☐ Ja ☐ Nei

Hvis ja, hva bruker du
(Oppgi produktnavnet på det du bruker og antall tabletter/kapsler/skjeer du tar hver gang)

- Multi vitaminpreparat ....
- Multi mineralpreparat ....
- Multi vitamin- og mineralpreparat ....
- "Pakkeløsninger" ....

Andre vitaminer
- Vit. A ....
- Vit. D ....
- Vit. E ....
- Vit. B ....
- Vit. C ....

Andre mineraler og sporstoff
- Kalsium ....
- Kalium ....
- Selen ....
- Sink ....
- Magnesium ....
- Jern ....
- Andre ....

Andre kosttilskudd
- Tran (flytende, kapsler) ....
- Omega-3 (flytende, kapsler) ....
- Urteekstrakter med jern ....
- Naturpreparat ....
- Kreatin ....
- Frie aminosyrer ....
- Protein ....
- Annet ....

....
....

7) Tar du disse preparatene regelmessig?

☐ Ja ☐ Nei

Hvis ja, hvor regelmessig
- hele året ☐
- kun i perioder ☐ ....

Merknader
....
....

8) Hvorfor tar du kosttilskudd?

....

....

....

9) Er det noen som har anbefalt deg å ta kosttilskudd?

☐ Ja ☐ Nei

Hvis ja, hvem

....

....

10) Hvor lenge har du brukt kosttilskudd?

....

....

11) Betaler du selv for preparatene?

☐ Ja ☐ Nei

Hvis nei, hvem betaler for preparatene

- familie/foreldre ☐
- særforbund/laget ☐
- produsent ☐
- andre ....

12) Bruker du sportsprodukter (sportsdrikke, sportsbar, restitusjonspulver etc)?

☐ Ja ☐ Nei

Hvis ja, hvilke

....

....

Hvis ja, når

....

....

13) Tar du spesielle kosthensyn i forbindelse med treningstidspunkt (før, under, etter)?

☐ Ja ☐ Nei

Hvis ja, hvilke

Før:

....

....

Under:

....

....

Etter:

....

....

14) Har du noen gang tidligere fått noen form for kostveiledning?

☐ Ja ☐ Nei

Hvis ja, fra hvem

....

Appendix 7: An example of the feedback the participants received

Oslo, 12.01.2008

Kjære deltaker,

tusen takk for flott innsats i forskningsprosjektet *"Validering av energiinntak målt med 4-dagers veid kostregistrering blant toppidrettsutøvere ved hjelp av energiforbruk målt med Senswear Pro Armband"*.

Vedlagt finner du en vurdering av kostholdet ditt, basert på de fire dagene du veide og registrerte inntaket ditt. Dersom du i tillegg målte kroppssammensetning (DXA) og jernstatus (blodprøve), står disse resultatene i henholdsvis tabell 3 og 4 på side 1. I tillegg til kostvurdering, får du også kopi av dine resultater fra målingen av energiforbruk. På siste side finner du forlaringer til hvordan du skal tolke disse resultatene.

Hvis du har noen spørsmål vedrørende tilbakemeldingen eller ønsker å få en nærmere gjennomgang av resultatene dine, send mail til marianne.udnaseth@studmed.uio.no.

Det er fortsatt mulighet til å måle kroppssammensetning (DXA) for dere som ennå ikke har gjort det. Som nevnt tidligere er ikke det en obligatorisk del av studien, men noe vi oppfordrer dere til å gjøre. Det er en verdifull måling for alle toppidrettsutøvere, som gir
tall på hvor mye muskelmasse og fettmasse du har, samt fordelingen av dette i kroppen. I tillegg måler den beintettheten din.

Vennlig hilsen

Marianne Udnæseth
Masterstudent i klinisk ernæring
Universitetet i Oslo

Christine Helle
Ernæringsfysiolog
Olympiatoppen

OLYMPIATOPPEN

Tilbakemelding NN

Periode: Oktober 2008

Tabell 1: Inntak av næringsstoffer

	Ditt daglige inntak		Anbefalt daglig inntak
	Uten kosttilskudd	Med kosttilskudd	
Energi (kcal)	5376	5634	
Fett (g)	180,8	187,7	
Protein (g) **Protein (g per kg)**	201,0 2,3	201,1	 1,2-1,8
Karbohydrat (g) **Karbohydrat (g per kg)**	718,4 8,2	-	 6-10
Kostfiber (g)	41,0	-	35
Jern (mg)	27,6	-	9
Kalsium (mg)	2217	-	800
Vitamin C (mg)	73	-	75
Vitamin D (µg)	5,8	-	7,5

Tabell 2: Fordeling av energigivende næringsstoffer

	Din fordeling	Anbefalt fordeling
Protein (%)	15	12-20
Fett (%) **- mettet fett (%)** **- umettet fett (%)**	30 11 16	25-30 < 10 > 15
Karbohydrat (%) **- sukker (%)**	55 11	55-65 < 10
Alkohol (%)	0	0

Forklaring til anbefalingene: Anbefalingene gjelder for mannlige utøvere i utholdenhetsidretter med minst 1 økt daglig. Anbefalingene for karbohydrat og protein uttrykt i gram pr kg kroppsvekt (tabell 1) angir ditt absolutte behov. Anbefalingene for karbohydrat, protein og fett uttrykt i prosent (tabell 2) viser hvor mye de tre næringsstoffene bør bidra med av ditt totale energiinntak. Anbefalingene for fordeling av de energigivende næringsstoffene angir den ideelle sammensetningen av kostholdet til idrettsutøvere. Det er først og fremst det absolutte behovet (tabell 1) det er viktig at du får dekket.

Tabell 3: Kroppssammensetning (målt med DXA)

Muskelvev (kg)	77,9
Fettvev (kg) **Fettvev (%)**	5,4 6,5
Beintetthet	Høy

Tabell 4: Jernstatus (blodprøver)

	Din verdi	Anbefalt verdi
Hemoglobin (g/100 mL)	14,7	13,4-17,0
Serum Ferritin (µg/L)	52	20-300

Vurdering av kostholdet ditt

Proteininntak:
Av tabell 1 ser du at du får i deg nok proteiner gjennom den kosten du spiser. Rene fileter av kjøtt, fisk og kylling er bedre proteinkilder enn pølser, salami og kjøttdeig (blandingsprodukter). Melk, yoghurt, egg og ost er også gode proteinkilder.

Karbohydratinntak:
Karbohydratinntaket ditt er bra! Fortsett å velge gode karbohydratkilder som grovt brød, korn, pasta, ris, potet, frukt og grønnsaker.

Inntak av jern, kalsium, vitamin C og vitamin D:
Inntaket ditt av jern og kalsium er veldig bra, og du ser av tabell 1 at du dekker behovet ditt for disse næringsstoffene. Vitamin C og vitamin D får du for lite av. Vitamin C inntaket kan du enkelt øke ved å spise mer frukt og grønnsaker (se kommentar under matvarevalg). Behovet for vitamin D kan være vanskelig å dekke via kosten, så sant man ikke spiser mye fet fisk som pålegg og til middag. Det kan derfor være lurt å ta et trantilskudd for å sikre at du får i deg nok vitamin D og omega-3 fettsyrer. I tillegg bør du prøve å få i deg gode vitamin D kilder fra kosten, slik som makrell, laks, ørret, margarin og ekstra lett melk.

Matvarevalg:
Du velger mange bra matvarer som grovt brød, havregryn, kornblanding, margarin, lett melk, yoghurt, hvitost, leverpostei, kylling, fisk, juice og litt frukt og grønnsaker. Bær, frukt og grønnsaker bør du spise mer av for å sikre at du får i deg nok vitaminer og naturlige antioksidanter. Du spiser i gjennomsnitt 2 porsjoner frukt og under 1 porsjon grønnsaker per dag. Husk ”5 om dagen”! Drikk et glass appelsinjuice til frokost, pynt brødskivene med paprika, agurk og tomat, spis frukt og grønnsaker som mellommåltider og dessert etter måltider, og spis alltid en god porsjon salat/grønnsaker til middag. Du har en fin fordeling av næringsstoffer i kosten din (tabell 2). Du ligger noe over det anbefalte inntaket av sukker og mettet fett. Et litt høyt sukkerinntak skyldes bruk av mye søtpålegg som prim og brunost, samt inntak av brownies, muffins og brus. Varier med proteinrike pålegg som fisk, egg, hvitost og skinke- og kalkunpålegg, og begrens inntak av kaker og søtt. Mettet fett får du hovedsakelig i deg fra blandingsprodukter av kjøtt, som pølser og kjøttdeig, men også fra kaker og fete oster. Velg rene fileter av fisk, kjøtt og kylling, som inneholder mindre mettet fett og i tillegg er bedre proteinkilder.

Måltidsrytme:
Du har en god måltidsrytme med mange måltider jevnt fordelt utover dagen.

Kostråd i forhold til treningsøktene:
Det er viktig at du spiser nok før trening slik at du er i energibalanse på hele treningsøkten. Et karbohydratrikt måltid 1-3 timer før økten starter vil medføre en siste fylling av glykogenlagrene og regulering av blodsukkeret. Før økter med styrketrening eller lange utholdenhetsøkter bør du ha et bra proteininntak i tillegg til karbohydratinntaket for å sikre optimal proteinomsetning. Du har bra måltider de siste 1-3 timene før trening.

Idrettsutøvere anbefales å drikke på alle økter som varer mer enn 30 minutter. Det er da viktig å drikke så mye at du ikke har et væsketap som overstiger 2% av kroppsvekten. Du drikker 5-12 dl vann per time trening. Dette er tilstrekkelig i forhold til ditt væsketap. Du bør drikke minst 5 dl per time trening. I varmt klima kan det være nødvendig å drikke mer.

Du har et karbohydratinntak under trening på 37 gram per time, når du har økter over 60 min. Dette er tilstrekkelig for å sikre høy kvalitet på lange og/eller harde økter. Karbohydratinntak under trening vil øke arbeidskapasiteten din dersom du tømmer glykogenlagrene dine og/eller får lavt blodsukker i løpet av økten. For deg vil dette sannsynligvis være treningsøkter som varer mer enn 60-90 min., avhengig av intensiteten. Anbefalingen for slike økter er å innta 30-60 gram karbohydrat per time trening i form av en sportsdrikke med 4-6% karbohydrat (tilsvarer 4-6 gram per dl vann). Du kan også få dette karbohydratinntaket fra mat med høy glykemisk indeks (energibar, moden banan, rosiner, loff med syltetøy etc), men pass da på at du tygger maten godt og drikker vann til. Energibarer gir 20-40 gram karbohydrat (se på pakken), 1 banan gir 20-25 gram, 1 dl rosiner gir 40 gram og 1 skive loff med syltetøy gir 20-25 gram.

Du er flink til å få i deg mat og drikke umiddelbart etter trening, noe som gir grunnlag for optimal restitusjon. Etter alle treningsøkter er det viktig å innta væske, karbohydrat og protein for at restitusjonsprosessene skal bli optimale. Du skal erstatte væsketapet ditt med 150% av væsketapet du har hatt i løpet av treningen. Det betyr at mengden du trenger vil avhenge av hvor mye du har drukket under økten. Prøv uansett å drikke minst 5 dl direkte etter økten og fortsette å drikke til du har tisset 2 ganger. Etter lange økter og i varmt klima må du sannsynligvis drikke vesentlig mer. Så bør du innta 1-1,5 gram karbohydrat pr kg kroppsvekt innen ½ time etter alle økter. Det kan du gjøre ved å spise et måltid med karbohydratrik mat og noe protein innen ½ time etter økten, for eksempel: a) 2-3 brødskiver med syltetøy og 1 glass melk; b) 2-3 brødskiver med proteinrikt pålegg (ost, fisk, kylling, kjøtt, egg) og 1 glass juice til; c) 1,5 dl kornblanding med 1 ss syltetøy og 2 dl melk eller yoghurt; d) varmrett med 150-200 gram pasta, ris eller poteter og litt fisk, kylling, kjøtt eller egg.

Når du ikke har anledning til å spise et måltid innen ½ time, bør du få i deg noe karbohydratrik drikke og/eller mat (fruktjuice, frukt, energibar, rosinboller, brød, rosiner) innen ½ time. De følgende mengder gir deg 100 gram karbohydrat alene: 2 energibarer, 4 bananer, 2 dl rosiner, 3 rosinboller, 4 skiver loff med syltetøy. Deretter bør du spise et blandet måltid som også gir protein (melk, egg, fisk, kylling, kjøtt) raskest mulig (innen 2 timer etter avsluttet økt).

Lykke til!

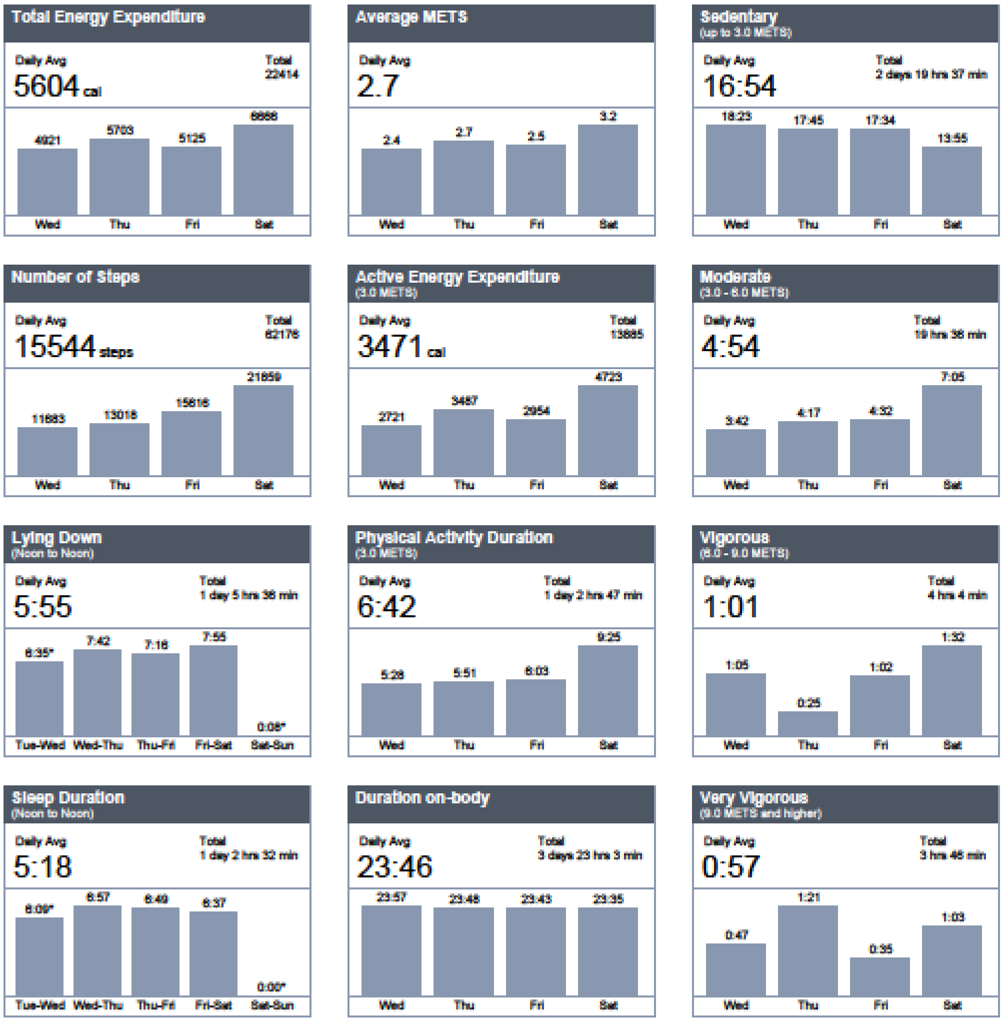
InnerView Report Created Wed 10, Dec 2008 Page 1 of 1

created by BODYMEDIA

Clinician / Physician	Hospital / Organization	Practice / Department

Subject	Age	Gender	Weight	Height	Handed	Smoker	BMI
2	18	Male	87.0 kg	193 cm	Right	No	23.36

Start Time	End Time	Duration of View	Duration on-body
Wed 10 Sep 2008 00:00	Sun 14 Sep 2008 00:00	4 days	3 days 23 hrs 3 min (99.0%)



* Partial Day. Value is not representative of a 24-hour timeframe.

Generell informasjon om resultater fra aktivitetsmonitoren SWA

Nedenfor presenteres kort forklart hva de ulike verdiene fra aktivitetsmonitoren betyr. For å få "godkjent" resultat, og bli innlemmet i gjennomsnittsdataene, må du ha gått med monitoren i minimum 4 dager, og 95 % av tiden. NB! Også i disse dataene er det en viss grad av unøyaktighet, spesielt med tanke på om dagene du brukte monitoren var representative/typiske for deg.

Forklaringer til resultatene:
Øverst på "InnerView report-arket" står det blant annet skrevet inn din høyde og vekt. Disse verdiene kan variere med noen hundre gram eller en halv centimeter fra de verdiene som er oppgitt på det andre resultatskjemaet. Grunnen til dette er at dataprogrammet til monitoren kun takler "hele" kilogram- og centimeter. Hvis det står oppgitt at du er høyrehendt, men egentlig er venstrehendt, så betyr ikke dette noe for målingene.

Vi har justert måleperioden til "hele" dager, dvs at om du fikk på deg minitoren på formiddagen, så er timene fram til klokka 00.00 tatt bort. Tilsvarende har vi gjort på slutten av måleperioden. I øvre del av arket står det "**Duration of View**". Står det f.eks "4 days" her, betyr det at du har gått med monitoren 4 dager. Ved siden av står det skrevet "**Duration on-body**". Dette betyr hvor mange prosent av tiden i løpet av disse 4 dagene du har gått med monitoren. Den tiden du ikke har hatt monitoren på armen, estimerer ("tipper") monitoren hvor mye du har vært i aktivitet (og da blir vanligvis aktivitetsnivået ditt underestimert). Jo nærmere 100 % tid på "duration on-body" du har, jo mer riktige blir dermed resultatene.

Om METS: 1 MET tilsvarer den energimengden du forbruker hvis du sitter, ligger, sover eller er helt i ro. Hvis du f.eks går en tur jobber du med en intensitet som er i størrelsesorden 3-5 METS. Rask løping kan f.eks gi verdier på 10-18 METS.

Total Energy Expenditure:	Beskriver hvor mange kilokalorier (kcal/cal) du brukte. Personer med stor kroppsvekt scorer normalt sett høyt her, jamfør lettere personer
Average METS:	Beskriver gjennomsnittlig METS-verdi. Høyere tall betyr høyt aktivitetsnivå. Under 1,4 er lavt. Over 2,0 er høyt.
Sedentary:	Beskriver hvor mange timer og minutter du har sittet i tilnærmet ro (< 3 METS), f.eks soving, spising, TV-titting, kontorarbeid osv
Number of Steps:	Beskriver hvor mange skritt du har tatt. Over 10.000 per dag er meget bra.
Active Energy Expenditure:	Beskriver hvor mange kcal du har brukt ved å være i aktivitet > 3 METS
Moderate:	Beskriver hvor mange timer og minutter du har drevet med moderat aktivitet (3-6 METS), som f.eks å gå, hagearbeid, snekring osv
Lying Down:	Beskriver hvor mange timer og minutter du har ligget og slappet av i f.eks senga eller på sofaen, inklusiv søvn
Physical Activity Duration:	Beskriver hvor mange timer og minutter du var fysisk aktiv > 3 METS
Vigourous:	Beskriver hvor mange timer og minutter du har drevet med relativt hard fysisk aktivitet (6-9 METS), f.eks jogging, arbeid som graving, løfting osv.
Sleep Duration:	Beskriver hvor mange timer og minutter du har sovet (NB - gjennomsnittet blir litt for lite, pga at siste døgn ikke taes med, se heller på enkeltdagene)
Duration on-body:	Beskriver timer og minutter du har hatt monitoren på armen
Very Vigourous:	Beskriver hvor mange timer og minutter du har drevet med meget hard fysisk aktivitet (> 9 METS), f.eks løping og annen hard trening.