SSE #150

Sports Science Exchange (2015) Vol. 28, No. 150, 1-6

GATORADE SPORTS SCIENCE INSTITUTE

DIETARY ASSESSMENT METHODS FOR THE ATHLETE: PROS AND CONS OF DIFFERENT METHODS

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KEY POINTS

- Different protocols are available for collecting data on the eating practices of athletes according to the goals and available resources of the activity.
- Retrospective methods (e.g., food frequency questionnaires and diet history) are limited by the athlete's insights and memory, while prospective methods (e.g., food diaries) are limited by the tendency for the act of recording to alter usual intake.
- Food diaries are a frequently used dietary assessment in research and athlete support, but should be checked for the common bias of under-reporting.
- New technologies provide the potential for more rapid and efficient dietary assessment protocols, but like all methods, need to be validated for use with athletic populations.

INTRODUCTION

Investigating what an athlete eats is a daily activity for a sports dietitian, so it would be expected that the practice would make it an efficient and effective task. However, dietary assessment remains a challenge in sports nutrition, with the potential for significant errors of validity and reliability. These errors challenge the accuracy of estimates of what the athlete actually ate, or usually eats, and may also prevent the detection of a real change if an assessment is repeated. Developing expertise in this activity requires an appreciation that there are different reasons for undertaking an assessment, different approaches to completing it and different tools that can be employed. Therefore, the outcome can be enhanced by matching the best approach to each specific situation. Nevertheless, there is also a need to take into account the errors involved in a dietary assessment when interpreting the data that is collected. This Sports Science Exchange article outlines the available options as well as an understanding of how the results of an assessment need to be viewed in light of the residual limitations. It needs to be remembered that almost all interrogations of dietary survey methods have been undertaken on non-athletic populations; therefore, some of the commentary is by necessity based on professional experience rather than sound research. Further general information on dietary survey methodology is available from the excellent reviews of Bingham (1991) and Thompson and Subar (2008).

REASONS FOR COLLECTING DIETARY INFORMATION

Two basic scenarios explain why athletes might want to collect information about their food intake. In the first, the interest is in measuring what an athlete actually eats during a period in which they make their own choices. The chief goal of this activity, typically termed a dietary assessment, is to investigate what is happening without influencing the process. This scenario occurs in sports nutrition in a variety of situations of both research and athlete servicing, each with its own challenges and specific goals (Table 1) Generally, dietary assessment methods are divided into strategies that are retrospective (what the athlete ate in the past) and those that are prospective (what happens over a period in the future). There have been four main methods used over the past 50 yrs to assess the dietary practices of athletes (Table 2).

The second scenario, often known as diet tracking or self-monitoring, takes advantage of a limitation of many dietary assessment methods – that an individual will change his or her food intake during the process of monitoring it. A key tool in assisting an athlete to alter his or her dietary practices is to increase their self-awareness of their behaviour and the factors that underpin it. An athlete is likely to improve their food choices and portion control when they are accounting for their actions in real-time or directly associating their behaviour with an outcome. Receiving positive feedback about improvements in dietary practices and identifying the factors that support it can be valuable strategies in consolidating new habits. The protocols and tools used for dietary tracking activities may be different from those of dietary assessment because of the altered goals, and are discussed in a separate Sports Science Exchange article.

RETROSPECTIVE MEASUREMENTS OF DIETARY INTAKE

Retrospective methods include the dietary history (a guided interview usually used to gain insights on habitual intake, often framed as a typical day), the 24 h recall (which investigates intake over a specific day) and the food frequency questionnaire (a summary of usual intake of different categories of foods). A general principle common to each of these techniques is that they are heavily reliant on the athlete's ability to recall the types and quantities of foods and drinks consumed over the period of interest in the past. These methods fall short when the athlete is embarrassed/unwilling to reveal his/her true

	EXAMPLE	COMMENTS
DIETARY	Descriptive study of the eating practices of a group of athletes	Usually, the scientific report from such a study compares the results to sports nutrition guidelines or to literature reports from other athletic groups. Sometimes, there may be sufficient numbers of athletes in the survey to make comparisons between different groups or different periods of observation. Typically, the outcomes are reported as mean/spread of intakes of energy, macronutrients and micronutrients, although sometimes, there may be a grading on the proportion of athletes who fail to meet a recommendation. Some studies focus on specific periods (e.g., training vs. competition practices) or specific nutritional practices (e.g., weight-making practice or carbohydrate-loading practices).
	Study of special dietary requirements of athletes	Typically, a parameter of nutritional status is measured (e.g., iron status, micronutrient status, muscle glycogen stores) and correlated with dietary intake of key nutrients. Studies of small samples cannot establish true nutrient reference values but may identify whether athletes have increased requirements for some nutrients or set general dietary targets (e.g., guidelines for daily carbohydrate intake for training).
	Study of relationship between dietary intake and issues of athlete nutritional status, health or performance	Typically, a parameter of interest (e.g., illness rates, bone health, menstrual status, performance) is measured in a group of athletes and correlated with parameters of dietary intake. Cross-sectional studies can only show relationships rather than cause and effect.
	Longitudinal studies of dietary intake, including changes due to an intervention	Studies are often interested to investigate changes in dietary intake due to a planned intervention (e.g., nutrition education or counselling) or random change (e.g., move to a different living environment). Sometimes the study will also measure changes in an outcome of interest (e.g., performance or health parameter) and try to link it to dietary changes.
	Dietary standardization strategies	In studies of athletic performance, dietary intake is standardized for a period (e.g., 24-48 h) prior to testing in an attempt to improve the reliability of the performance measure. Assessment of intake during the standardization period is often undertaken to check compliance to the study protocol.
	Athlete servicing work	Sports dietitians who work with individuals or groups of athletes will want to assess past and current eating practices, linking these to health and performance outcomes.
DIETARY TRACKING	Dietary tracking	A record of food intake is undertaken to increase the athlete's self-awareness of their food intake and eating practices. The record may require the athlete to identify factors that influence their food intake (e.g., the food environment, hunger, emotions) or the outcomes of eating (e.g., performance at training, gut comfort). Special focus may be targeted to behaviours the athlete wants to change to help them to consolidate new practices.

Table 1: Examples of scenarios of dietary assessment or dietary tracking in sports nutrition

eating patterns or unable to provide good descriptions of the type and amount of items in his/her past intake. The 24 h recall is the least frequently used protocol, because situations in athlete practice or research in which we are only concerned about what happened on a single day are not as common as other interests. Food frequency questionnaires and dietary histories generally attempt to assess intake over longer periods of time, which is valuable in gaining a longer-term perspective on eating patterns. However, these techniques are reliant on the athlete's memory and insights into their true intake and suffer when the athlete is a poor historian and/or has a complicated lifestyle that is difficult to summarize.

The dietary history is commonly used by sports dietitians to gain initial insight into an athlete's dietary practices. Although it does not lend itself to an accurate quantitative assessment of nutrient intake, it is valuable for gaining insight into the pattern of meals, snacks, intake around training sessions/events and supplement use. It requires a skillful interview technique to gather information with minimal bias, to cross-check the information, and to probe for factors that contribute to the patterns of intake. Although it is challenged by the athlete's ability to accurately describe the usual portion sizes of their food and drink choices, the use of models or pictures of food sizes can assist the athlete to better describe the quantities they consume.

Food frequency questionnaires (FFQ) can be implemented by a trained interviewer, but can also be self-administered by the athlete, using paper or an electronic format, to save time and resources. Asking athletes to identify how often they eat a range of individual food/drink items may gain a summary of the total diet, but tends to overestimate intake in low-energy consumers and under-estimate intake in large eaters. Importantly, it strips away some of the information that sports dietitians are interested in – for example, when a food or drink is consumed and what else is consumed at the same time. Food frequency questionnaires are most useful to assess the intake of a particular nutrient or food factor of interest – e.g., antioxidants or calcium – where, ideally, the FFQ has been validated by comparing responses to a biomarker of the intake or nutritional status of the compound (Braakhuis et al., 2011). Again, models or pictures of foods and portion sizes can help to enhance the accuracy of the identification or quantification of dietary intake.

	OVERVIEW OF METHODS	PERIOD OF INTEREST	PROS	CONS
RETROSPECTIVE				
24 h recall	Subject describes foods consumed over the last 24 h or a "typical day"	24 h	• Speedy to implement • Low burden for the subject • Interview can be structured around daily activities • Does not alter intake • Suited to epidemiological research	• Relies on subject's honesty, memory and food knowledge • Requires trained interviewer • Day for recall may be "atypical" • Suitable for group surveys, but not representative of individual's normal intake
Food Frequency Questionnaire (FFQ)	Subjects asked how often they eat foods from a standardized list and to estimate portion sizes often using photos or food models as a prompt	From 24 h period to open-ended	• Can be self-administered to lower burden on the investigator • Can be used to cross-check data obtained from other methods • Validated for ranking individuals • Can be modified to target certain nutrients • Can be automated to allow quick processing by investigator	• Relies on responder's honesty, memory, literacy and food knowledge • Validity dependent on the food list and the quantification method
Diet history	Open-ended interview concerning food use, food preparation, portion sizes, food like/dislikes and a food checklist	Open-ended or over a specified period	• Accounts for daily variation in food intake by investigating a "typical" day • Can target contrasts between periods of interest as a sub-theme • Collects information on timing of intake and factors that influence food patterns	• Relies on responder's honesty, memory, food knowledge • Labour intensive & time consuming • Requires trained interviewer • Mostly appropriate for qualitative assessment rather than quantitative
PROSPECTIVE				
Written food diary (diet record)	Weighed	May be undertaken for 1–7 d, with increasing ability to track usual intake as duration increases, but reduced compliance	• Provides a more accurate quantification of foods than household measures • Considered the "gold standard for dietary assessment"	• Relies on participant's honesty and food knowledge • Time consuming for subjects to keep and investigator to process • Distorts food choice and quantity: Subject alters their diet to improve their intake or to reduce the workload of recording
	Household measures (descriptions of cups, teaspoons, dimensions of food portions, etc.)		• Improved compliance with subjects compared with weighed record • Less alteration of normal eating pattern compared to weighed or semi-weighed records	• See comments for weighed record • Requires checking by trained person • Needs standardized set of household measures • Subjective/inaccurate assessment of portion sizes

Table 2: Traditionally used methods for collecting dietary intake information

PROSPECTIVE MEASUREMENTS OF DIETARY INTAKE: THE FOOD DIARY

The food diary or diet record is the most popular dietary assessment protocol in sports nutrition research and practice. Having an athlete record what he/she consumes over a nominated period sounds like a simple task, but in reality, there is great complexity in making this exercise a meaningful one. Food diaries propose to monitor intake over a specific period that represents a generalized period of interest. This period may vary from a short-term dietary program (for example, the 48 h period prior to undertaking a research trial or a cyclist's intake during a multi-day stage race) to the athlete's typical diet. Variations on the traditional food diary technique include the number of days that are recorded and the method of quantifying food portions (e.g., direct weighing techniques or description via household measures and dimensions). Traditional paper and pen methods of recording place a large burden on the athlete and assume he or she is literate, motivated and organized enough to faithfully record their intake for the required period.

There are several sources of error in prospective assessments:

a) The athlete alters his/her eating patterns or food choices during the period of recording the food diary so that it does not reflect his/her usual intake.

b) The athlete records his/her dietary intake inaccurately to improve the perception of what he/she is eating (i.e., he/she omits or underestimates the intake of foods or meals seen as undesirable, or falsely reports the intake of foods seen as desirable).

c) The athlete makes errors of quantification or description in recording his/her food intake.

Food diary protocols typically have trade-offs. For example, the weighed food record provides confidence in the accuracy of quantified information. However, having to weigh all food items – including individual components of a meal or dish – increases the burden on the athlete and usually leads to changes in food intake, whereby the athlete chooses foods that are simpler to process or skips the eating occasion entirely. Another trade-off is the duration of the food diary: An increase in the number of days of recording increases the likelihood that it represents the usual intake, but reduces the compliance shown by the subject in keeping an accurate record.

In the general population, a 3-4 d food diary is often considered the "middle ground" for investigating the intake of a group, but it is not often recognized that it provides a poor estimate of the true intake of individuals. Because we eat differently from day to day, there is considerable variability in our daily intake of energy and nutrients. Some dietary characteristics are stable, while other nutrients are less evenly distributed in foods, meaning that daily intakes fluctuate markedly and affect the precision of the estimate from a food diary (Basiotis et al., 1987 Braakhuis et al., 2003). A study of the general population (Basiotis et al., 1987) suggested that, 1) 14-30 d of records may be required to estimate an individual's intake of even the most stable nutrients to within 10% of their true long-term intake, 2) at least 7 d are needed to rank individuals within a group as high or low consumers, and 3) several orders of magnitude more are needed to accurately assess an individual's intake of variable nutrients. In addition, 4) having at least 15 subjects in a survey would allow a reasonable estimate of group average intake of stable nutrients (energy, carbohydrate) within 4-5 d of records, 5) moderately stable nutrients (e.g., iron) might require double the sample size or days recording, and 6) highly variable nutrients (e.g., vitamins A and C, cholesterol) could require >40 d or >200 subjects to derive a precise assessment (Basiotis et al., 1987). A practical way to gain a longer recording interval is to have groups or individuals keep several shorter records over a period of time, thus building up the total number of recorded days while reducing the drop-off in recording compliance.

Few studies have examined the optimal recording period for athletes by looking systematically at issues of recording compliance or day to day variability in food/nutrient intake. Professional experience suggests that some athletes are diligent – or even over-fastidious – at record keeping, accustomed to measuring aspects of their life in accurate detail and motivated by the idea that the activity could lead to better performance outcomes. Such individuals may be able to record a 7 d food diary with little burden and careful precision. Being able to monitor the duration of a training microcycle is useful since it allows an assessment of how well patterns of food/fluid intake track with the changing needs of workouts and competition. Repeating such an assessment at different times of the periodized sporting calendar would build up a useful picture of the athlete's dietary practices. In contrast, other athletes are poor candidates for food diaries as an overcommitted lifestyle can leave little time or enthusiasm for real-time recording of food intake while the imposition by a coach of an effort-requiring activity when the athlete is disinterested in nutrition is unlikely to achieve a useful outcome.

ERRORS OF MISREPORTING IN FOOD DIARIES

The different errors in food diaries affect the outputs in different ways. In some cases, the error involves inaccurate recording (the athlete ate food that he/she did not account for) while in others, the problem is atypical eating (the athlete ate the food, but it does not reflect his/her typical practices). Extensive study of the accuracy of food diaries in the general population has found that the bias of misreporting errors is towards under-reporting usual dietary intake. A systematic review found that ~30% of respondents in dietary surveys significantly under-reported their true intake and that across studies, energy intake was under-reported by ~15% (Poslusna et al., 2009). Factors that seem to predict under-reporting in the general population include being a high-energy consumer, being overweight and/or being weight conscious (Livingstone & Black, 2003).

While it is tempting to apply a correction factor across the board to the results of studies, this is inappropriate for individuals, since in any group survey there are likely to be individuals who significantly over-report energy intake, those who under-report and those whose reported intake is within reasonable agreement. Furthermore, there is evidence that even if the degree of misreporting of energy can be ascertained, it does not necessarily correlate with the misreporting of nutrient intake. Certain types of foods or eating occasions are more likely to be misreported than others, either due to the inconvenience of reporting (e.g., snacks), failure to recognize that they represent intake (e.g., foods and drinks consumed during exercise) or the desire to appear to eat better than in reality (e.g., reduction in high fat and sugary foods, increase in fruits and vegetables).

In general nutrition, researchers try to validate dietary survey methods or the collected data with three different approaches. They may compare the information that is collected against the results from another method, e.g., FFQ vs. a food diary. This is not entirely satisfactory since it generally involves comparing one set/type of errors against another. Comparison to an observation of actual intake is a possible validity exercise, but is complicated to achieve, particularly over the long term. A comparison to an independent marker of nutrient intake or status is generally the preferred method, with options including comparison of self-reported protein or sodium intake to urinary measures of nitrogen or sodium (Hedrick et al., 2012). Little research of this type has been undertaken on athletes.

The most common approach to checking the validity of a food diary is to compare energy intake against a theoretical or measured assessment of energy expenditure, taking changes in body composition to estimate energy surplus or deficit, and thus, a marker of under- or over-recording of usual/required intake. In research settings, energy expenditure can be measured in a metabolic chamber or, in free-living subjects, with doubly labeled

water (Livingstone & Black, 2003; Trabulsi & Schoeller, 2001). Several sophisticated energy balance studies have been carried out on athletes and most have found discrepancies between reported energy intakes and energy requirements (Magkos & Yannakoulia, 2003). Prediction equations and wearable tracking devices (e.g., Sensewear) offer another level of assessment of energy expenditure in both research and practical settings, although some caution is needed regarding their ability to accurately represent the energy cost of high-level athletic activities. Many researchers and practitioners adopt the Goldberg cut-off (Goldberg et al., 1991), which looks at a reported energy intake relative to measured or predicted basal metabolic rate to identify implausible habitual eating patterns and thus significant misreporting in a food record (Livingstone & Black, 2003).

ERRORS IN QUANTITATIVE NUTRIENT ANALYSIS

Although researchers and practitioners often assess dietary intake data qualitatively, by examining patterns of food intake in light of recommended nutrition behaviours, the goal of many dietary assessment activities is to gain a quantitative assessment of energy and nutrient intake. The traditional achievement of this quantitative assessment involves interpretation by the investigator of the self-reported food data (e.g., the food diary), coding decisions and data entry into a computerized dietary analysis program. Such programs access a food composition database that varies in terms of the source of the food composition data, the number of foods that are included, the range of nutrients for which data are available and the method of analysis used in obtaining the nutrient data. Although computer dietary analysis programs are now widely available and easy to use, it is recommended that data entry and interpretation of dietary survey information remain the role of appropriately trained investigators using standardised techniques and cross-checking (Braakuis et al., 2003). This may help to eliminate errors and reduce the variability in decisions such as quantifying portions of foods described by subjects, and matching food descriptions to foods contained in the database. Of course, the availability and validity of food composition data in these analysis programs represents a major limitation at the end of the dietary assessment process.

NEW TECHNOLOGIES FOR DIETARY ASSESSMENT

Traditional methods of dietary assessment were largely developed as "paper and pencil" activities although in some cases, like FFQs, there was an early evolution of questionnaires into electronic formats that could be filled out and assessed automatically. Such mechanization substantially reduces the burden both to the subject and the assessor. However, over the past decade, technological advances have allowed the evolution of a host of new options to replace written questionnaires and diaries. There is a wide selection of new ways in which food intake information can be collected and processed, harnessing the utility, portability and ubiquity of present-day electronic gadgets (Table 3). Many of these options provide variations on the food diary with features that are suited to dietary assessment and/or dietary tracking tasks. Studies are currently being conducted to identify how well the features of these technologies and techniques can enhance the process of gathering information on food practices of special populations including athletes (for reviews, see Illner et al., 2012; Lieffers & Hanning, 2012; Stumbo, 2013). Although tempting to simply compare the outcomes to the results collected by another survey technique, it is hoped that studies will be undertaken to validate dietary data against better "ground truth" measures such as biomarkers or direct observations of food intake. It is likely that despite some of the potential or actual advantages of these new techniques, there will always be residual problems with gaining self-reported dietary information from any population.

PRACTICAL IMPLICATIONS AND SUMMARY

1. The following issues should be considered when choosing a dietary assessment method:
    - Validation: Has the technique been validated or explored in relation to athletes?
    - Burden on the subject: How complicated, time consuming or intrusive are the demands?
    - Characteristics of the subject: How literate, motivated and knowledgeable about food is he/she? What does he/she want to get out of the exercise?
    - Burden on the researcher: How much time, expertise and resources are required to collect and process the information?
    - Survey environment: What challenges are placed on the athlete during the assessment period? Will he/she be distracted or threatened by the information that is being collected?
    - Features of interest: Are we interested in the intake of energy, macronutrients, micronutrients, other food chemicals, time of consumption over the day or in relation to exercise, or interaction of nutrients consumed at the same time?
    - Assessment outcomes: Do we want quantitative, qualitative or ranking information?
    - Are we interested in usual intake over a long period or specific intake over a short period?

2. Where prospective methods are used (e.g., food diaries), it is reasonable to expect that most athletes will under-record or under-consume their usual intakes:
    - Athletes who are weight/physique conscious or dissatisfied with their body image are at highest risk of significant under-reporting errors.
    - Best accuracy in self-reported dietary assessments might be expected from athletes who are confident of their eating habits and body image, and motivated to receive valuable feedback.
    - Training of subjects is likely to enhance their record-keeping skills.

EXAMPLES OF NEW PROTOCOLS	POTENTIAL BENEFITS ASSOCIATED WITH NEW TOOLS AND TECHNIQUES
▪ Web-based food frequency questionnaires and 24 h recall systems using images to guide food portion selections ▪ PDA (Personal Digital Assistant) platforms for recording food diaries electronically from food database ▪ Smart card technology to record meals chosen by inmates of a closed environment (e.g., hospital, school, prison) ▪ Smartphone and tablet apps for directly recording intake of foods from personalised food database, processing nutrient composition and transmitting data to sports nutrition professionals ▪ Digital photography on mobile smartphones that time stamps and confirms food intake ▪ Includes technology that can even identify and quantify food intake from these images	▪ Enhancement of compliance with recording food intake in real time since the electronic device (e.g., mobile phone) may already be an habitual accessory in the athlete's lifestyle ▪ Alternative techniques to gain information on food/fluid descriptions (e.g., from scanned bar codes) or portion sizes (e.g., automated calculations from digital photos) or food that may be less reliant on the subject's motivation or food literacy ▪ Less bias in altering typical food patterns since the act of recording (e.g., scanning, photographing) may be less intrusive, thus reducing the self-consciousness or burden associated with self-reporting ▪ In the case of digital-savvy populations, which includes most athletes, familiarity and ease of use ▪ Ability to automatically interface information on food and fluid intake into databases for food composition analyses, assessment and feedback: minimises handling errors and time burden on the researcher/sports dietitian ▪ Ability to transfer information electronically and in real-time, enabling rapid and remote interaction with the sports nutrition professional or other feedback sources ▪ Electronic integration with other data such as training log, energy expenditure calculations, health and physique parameters

Table 3: New technologies and techniques for dietary assessments

- Processing of data from food records should be undertaken by a qualified professional using standardized techniques.
- Outputs from food diaries should be interpreted in light of under-reporting and misreporting issues, with checks of energy intake against measured or predicted energy expenditure providing information regarding misreporting.

3. New technologies and techniques of dietary assessment offer the advantages of increased efficiency and lower subject/researcher burden. However, validation of these techniques is required before we can be sure of their pros and cons.

4. The interpretation of self-reported information on dietary intake should be carefully filtered using insights about the dietary assessment tool and the athlete who used it.

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