

Eating Patterns and Meal Frequency of Elite Australian Athletes

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We undertook a dietary survey of 167 Australian Olympic team athletes (80 females and 87 males) competing in endurance sports ($n = 41$), team sports ($n = 31$), sprint- or skill-based sports ($n = 67$), and sports in which athletes are weight-conscious ($n = 28$). Analysis of their 7-day food diaries provided mean energy intakes, nutrient intakes, and eating patterns. Higher energy intakes relative to body mass were reported by male athletes compared with females, and by endurance athletes compared with other athletes. Endurance athletes reported substantially higher intakes of carbohydrate (CHO) than other athletes, and were among the athletes most likely to consume CHO during and after training sessions. Athletes undertaking weight-conscious sports reported relatively low energy intakes and were least likely to consume CHO during a training session or in the first hour of recovery. On average, athletes reported eating on ~5 separate occasions each day, with a moderate relationship between the number of daily eating occasions and total energy intake. Snacks, defined as food or drink consumed between main meals, provided 23% of daily energy intake and were chosen from sources higher in CHO and lower in fat and protein than foods chosen at meals. The dietary behaviors of these elite athletes were generally consistent with guidelines for sports nutrition, but intakes during and after training sessions were often sub-optimal. Although it is of interest to study the periodicity of fluid and food intake by athletes, it is difficult to compare across studies due to a lack of standardized terminology.

Key Words: dietary survey, energy intakes, CHO intakes, dietary practices

Introduction

There is a number of dietary surveys of Olympic and other elite-level athletes (10, 16, 19, 24, 34, 35) that present the intakes of energy and nutrients reported by their subjects in comparison to recommended dietary intakes for populations or to specific nutrient and dietary guidelines for athletes. To date, however, there has been little interest in the meal frequencies and eating patterns that underpin this nutritional intake. This information is important for a number of reasons.

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First, the spacing or periodicity of meals may play a role in meeting various goals of sports nutrition. The timing and frequency of energy or nutrient intake has implications for metabolism or nutrient availability, and can be manipulated to achieve specific nutrition goals. For example, nutritional guidelines for athletes already make specific recommendations about optimal timing of carbohydrate (CHO) intake before, during, and after exercise in order to enhance CHO availability (9). Therefore, it is of interest to see if athletes meet specific guidelines for the timing of nutrient intake within their total daily consumption.

Second, the elite athlete faces a number of unusual practical challenges to the achievement of their nutritional requirements. Issues such as a busy lifestyle, fear of gastrointestinal discomfort during exercise, or suppressed appetite after training may dictate opportunities for food and fluid intake over the day. The traditional eating pattern of “three square meals per day” may not be suitable for, or available to, the athlete. Indeed, a number of dietary surveys have commented on the “grazing” food patterns or high frequency of separate eating occasions in groups of athletes who report large energy intakes (10, 11, 14, 23, 28, 29, 31, 35). In these studies, the estimated contribution of “between meal snacks” to total daily energy intake was high, 25–37% of the total daily energy intake (11, 14, 28, 35). However, the existing data are limited in number and, in these studies, the definition of an eating occasion and the distinction between “meals” and “snacks” were not always made clear. Therefore, a more systematic investigation of the way that athletes schedule food intake into their daily timetables is needed.

The aim of this study was to undertake a dietary survey of a large group of elite athletes, who were part of the 1996 Australian Olympic team. We were interested to investigate the reported intakes of energy and macronutrients by these athletes and how these nutrients were spread into separate eating occasions each day. We devised a system of time-based cues to define meals and snacks eaten over the day, with a separate definition for energy consumed during training sessions. Since sports nutrition guidelines make recommendations for CHO and fluid intake during and after exercise, we also assessed how these nutrients were consumed in relation to training sessions. We considered whether gender or type of exercise / sporting activity affected the reported frequency and spread of energy and macronutrients over the day, and their eating/drinking behavior related to training.

Methods

Subject Recruitment

Approval for this study was obtained from the Australian Olympic Committee and the Ethics Committee of the Australian Institute of Sport. Data were collected from athletes during the 3–6 month preparation period before the 1996 Olympic Games, while they followed their typical training and eating patterns. We recruited subjects via a mailing, coordinated by the section manager representing each national sporting organization within the Australian Olympic Games team, and sent to each of the approximately 1000 athletes identified as potential members of the final Olympic team. This mailing contained a sheet summarizing the purpose of the study and the benefits to participants, detailed instructions on how to complete the survey, and a survey form comprising a brief questionnaire and a 7-day food and activity record. Once the mailing was completed, we attempted to telephone each potential team

member using the contact details provided by their national sporting organization. Subjects were invited to participate in the study if they were currently undertaking a full training program and living in their normal eating environment. We offered the following incentives to encourage athletes to participate in the study: We committed to provide each athlete with immediate feedback about their reported intake of energy and nutrients, and we offered prizes of nutrition education resources to 1 in every 25 athletes who returned a completed questionnaire and food record. Stamped self-addressed envelopes were provided in the survey kit.

Athletes undertaking interstate or overseas travel were eligible to participate only if this travel schedule represented their typical training routine and lifestyle. In our final sample, we only included athletes who were chosen to be on the Australian Olympic Team. In total we were able to contact 287 athletes who were eligible to participate in the study. We received usable data from 167 athletes, which represented 39% of the 424 athletes who competed on the Australian Team at the 1996 Olympic Games and 58% of the sample pool who could be contacted.

Classification of Athletes

We devised four major categories a priori to define sports activities, classifying each athlete who completed the survey with the category that best described the characteristics of their training and competition. The categories, similar to those used in other surveys of athletic groups (35), were endurance sports (ENDURANCE); sports requiring mainly sprint power, explosive power, or skill (SPRINT/SKILL); team sports (TEAM); and sports in which athletes are concerned about weight gain (WEIGHT). Subjects in our final sample were divided into the following groups:

- ENDURANCE: 4 canoeists, 2 cyclists, 11 distance runners, 3 kayakers, 9 rowers, 9 swimmers, and 3 walkers
- SPRINT/SKILL: 4 archery, 3 modern pentathlon, 6 table-tennis, and 4 sprint track or field athletes; 18 baseball and 8 softball players, 2 hockey goal keepers, and 9 shooters
- TEAM: 2 badminton, 5 basketball, 3 beach-volleyball, 8 hockey, 2 tennis, and 11 volleyball players
- WEIGHT: 6 boxers, 4 divers, 4 gymnasts, 5 judoists, 3 lightweight rowers, 1 weight lifter, and 5 wrestlers

Instruction of Subjects

During our initial phone contact, we provided subjects who agreed to participate in the study with detailed verbal instructions to support the written material included in the mailing. Each researcher read these instructions from a prepared script to ensure that a standardized message was given to each athlete. The verbal and written instructions provided information to standardize the collection of demographic information from subjects and the completion of a 7-day food record during a period of typical training. The following protocol for completing a 7-day food record was chosen and enforced:

- We asked subjects to record their intake of all fluid and foods, and all training sessions undertaken over the 7-day period. We asked them to make an entry in their food record sheets at the time of each activity, noting the time at which the activity was undertaken.

- We advised subjects of the benefits of keeping accurate and reliable records to ensure valuable personal feedback. Common issues leading to the alteration of usual eating patterns were discussed (e.g., omitting or changing foods that are hard to record, or that the subject feels they shouldn't be eating), with explanations of how to avoid or minimize these problems.
- We asked subjects to provide full descriptions of foods and fluids consumed according to features specified in the record. Specified features included the commercial brand names of packaged food, cooking or preparation methods, and food items added in preparation. In the case of composite foods and mixed dishes (e.g., pizzas, stir-fries, sandwiches), recipes or a full description of ingredients were requested.
- We asked subjects to quantify the portion of foods or fluids consumed, by referring to the weight or volume information provided on food packages or by using standardized household measures (e.g., standard teaspoons, tablespoons, cups). Foods that could not fit into a standard measure—for example, foods served in a single piece—were described by the dimensions of their shape, with a grid measured in centimeters being provided to allow these measurements to be done accurately.

During the instruction process, we offered subjects the opportunity to discuss specific methods for recording foods and drinks that they were likely to consume and considered “troublesome” (i.e., hard to describe or quantify). We documented any individual instructions given to subjects about troublesome and unusual foods, and prepared our own coding information for handling the analysis of these products.

Coding of Completed Food Records

All food records were coded and entered for computer dietary analysis by the same researcher (G.S.). On receipt of a completed questionnaire and food record, this researcher marked any ambiguous information on the sheets and immediately called the athlete to clarify the meaning of the entries. The number and type of training sessions undertaken during the 7 days of the diary were counted to ascertain the typical weekly training program.

The coding and quantification of food and fluid intake reported on each food diary was undertaken with reference to a manual specially prepared for this project. Our research team collated the manual prior to the commencement of the coding of food records in order to provide information on all foods likely to be consumed by our athlete population. This information included translations of quantitative descriptions of foods and drinks from household measures, dimensions, or commercial portions into gram amounts. It also summarized coding decisions that would need to be made for foods not appearing in the database of the computerized dietary analysis program, and provided details of the nutrient composition of foods that we had added to this database. In this way, the researcher coding the food records was able to standardize the descriptive and quantitative decisions made for each item recorded in the food diaries.

Periods of eating were broken into the following categories, based principally on time cues:

- Breakfast: 0500–0959
- Morning tea: 1000–1159

- Lunch: 1200–1459
- Afternoon tea: 1500–1759
- Dinner: 1800–2059
- Evening snack: 2100–0459
- Training: all energy-containing foods and fluid consumed during a workout

To distinguish the number of eating occasions reported each day, we experimented with 2 classification systems. First, we considered the intake of food or energy-containing drinks (defined as providing > 200 kJ) reported within the same 60-min period in the same location to constitute a single eating occasion. We then recoded the diaries to consider a single eating occasion as food or energy-containing drinks consumed within a 30-min period. Since each system produced a similar number of eating occasions recorded in a day, we decided only to report data based on the 30-min classification protocol.

We examined each training session for the reported intake of fluid or CHO. For each athlete, we calculated the percentage of the total number of training sessions in which they reported consuming both fluid and CHO (FLUID/CHO), those in which fluid only was reported (FLUID), and those in which the athlete did not report any intake (NIL). Recovery after each training session was assessed according to the guideline that the athlete should consume at least 0.8 g CHO/kg body mass (BM) within the first hour after a workout (27). Recovery after each training session was assessed as being fully achieved if the athlete had reported consuming a CHO intake > 0.8 g/kg BM during the hour after the session (RECOVERY), whereas we defined some attempt at recovery if reported CHO intake was 0.4–0.8 g/kg (ATTEMPT) and no recovery achieved if reported CHO intake was < 0.4 g/kg (NIL).

Dietary Analysis

The researcher first coded the food diary before entering the data into the dietary analysis program. A random check of data entries for each day of each record was completed to check for entry errors. The computerized dietary analysis package used in this survey was SERVE Nutritional Management System (v. 2.0, St. Ives, Australia) and was updated with information for composite dishes (recipes involving a combination of foods such as lasagna, casseroles, and sandwiches), commercial foods, and sports foods, where reliable nutritional composition data could be obtained. Data relating to reported intake of energy and macronutrients were examined from the dietary analysis sheets.

Statistical Analyses and Interpretation of Data

Although this survey of dietary behaviors of elite athletes is among the most comprehensive in the literature, the sample size is still not large enough to characterize small but clinically important differences between sex and sporting groups with acceptable precision. We have therefore not reported tests of statistical significance, lest readers reach erroneous conclusions about lack of differences between subgroups. Readers who wish to perform such tests or other analyses will be provided with these data as a tab-delimited text file on request.

We have used the mean and standard deviation (*SD*) to represent centrality and dispersion for subject characteristics and dietary behaviors of all athletes and of athletes in each sex and sport group. Uncertainties in the estimates of the means and

of the differences between means were derived from the *t* distribution as 95% confidence limits. To avoid clutter in the tables and to enhance interpretation of magnitudes, the confidence limits are shown separately as fractions of a standard deviation (*SD* units; Table 1). The confidence limits for the mean of a group are exact. The confidence limits for a comparison of sexes are an accurate approximation based on averaging variances of males and females. The confidence limits for comparison of sports are an appropriate average of the confidence limits for all pairwise comparisons. For some comparisons, we computed exact confidence limits using Proc Mixed in the Statistical Analysis System (v. 6.12, SAS Institute, Cary, NC, USA) to model unequal variances in the compared groups. Sample sizes are adequate to ensure normality of sampling distributions and therefore accuracy of the confidence limits, even for the markedly skewed variables representing alcohol intake (26).

We interpreted the magnitude of the difference between means and the magnitude of confidence limits using a modified version (25) of Cohen's (12) scale of effect sizes. The effect size is the difference between means expressed in *SD* units (a fraction or multiple of the standard deviation). The modified scale of effect sizes is as follows: trivial, 0.0–0.2; small, 0.2–0.6; moderate, 0.6–1.2; large, > 1.2. The confidence limits representing uncertainty in group means shown in Table 1 can be interpreted directly in terms of this scale: Uncertainty in the mean for all athletes is trivial, uncertainty in the means for females and males is trivial-small, and uncertainty in the means for sports is small. Although the uncertainty in the difference between means of sex or sport groups is also small, for most observed trivial differences, the confidence limits allow for the possibility that the true difference could be substantially positive and negative. We have considered such differences as not clear-cut.

The small sample sizes for males and females within each sport resulted in moderate uncertainty in the estimate of differences between means of these subgroups (± 0.72 *SD* units on average). This uncertainty represents poor precision of the estimate for all trivial and most small observed differences, because the corresponding true differences could be substantially positive or negative. We have therefore not shown tables of means and standard deviations for males and females within each sport. Precision of the estimate for moderate or large observed differences between sex and sport subgroups is more acceptable, and any such differences are reported in the legends of the tables and figures.

Results

The characteristics of the 167 athletes who completed this dietary survey are summarized in Table 2. The average age of the athletes who participated in the study was 25 years, with the female WEIGHT athletes younger than the other athletes, reflecting the inclusion of female gymnasts whose competitive peak is reached at an earlier age. Typically, athletes reported completing 9–10 individual training sessions per week during the period of the survey, and eating on five separate occasions each day. Differences between sexes or sporting groups are noted in Table 2.

Table 3 summarizes the daily intake of energy and macronutrients reported by the athletes, noting differences between sexes and sporting groups. The correlation between energy intake (MJ/d or kJ/kg/d) and the number of separate eating occasions each day was moderate ($r = 0.51$ for females and $r = 0.56$ for males).

Table 1 Sample Size and Consequent Confidence Limits for Means and Differences Between Means in Sex and Sport Groups

Variable	All	Sex		Sport			
		Female	Male	Endurance	Sprint/skill	Team	Weight
Sample size	167	80	87	41 (26 F, 16 M)	67 (29 F, 38 M)	31 (17 F, 14 M)	28 (9 F, 19 M)
Confidence limits ^a (<i>SD</i> units)	±0.15	±0.22	±0.21	±0.32	±0.24	±0.37	±0.39
Confidence limits for pairwise differences ^b (<i>SD</i> units)	—	±0.31			±0.47 (range, 0.40 to 0.53)		

Note. F, female; M, male; *SD*, standard deviation. ^aFor confidence limits of the true mean of a group, multiply the standard deviation of the group by this fraction, then add to and subtract from the observed group mean. ^bFor approximate confidence limits of the true difference between sexes or between two sports, multiply the average standard deviation of the two groups by this fraction, then add to and subtract from the observed difference between the group means.

Table 2 Age, Body Mass, Frequency of Training, and Eating in Sex and Sport Groups

Variable	All	Sex		Sport			
		Female	Male	Endurance	Sprint/skill	Team	Weight
Age (y)	25 ± 6	25 ± 6	26 ± 6	25 ± 5	27 ± 7	25 ± 4	23 ± 6
Body mass ^a (kg)	72 ± 14	63 ± 9	80 ± 12	69 ± 12	75 ± 12	75 ± 16	66 ± 16
Training sessions ^b (wk ⁻¹)	9.5 ± 3.4	9.7 ± 2.9	9.2 ± 3.8	11.6 ± 2.8	8.3 ± 3.3	8.0 ± 2.8	10.6 ± 3.0
Eating occasions ^c (d ⁻¹)	5.1 ± 1.1	5.1 ± 1.1	5.0 ± 1.1	5.6 ± 1.1	4.9 ± 1.2	5.2 ± 1.1	4.7 ± 0.8

^aLarge and clear-cut differences in body mass: males > females; female endurance, female sprint/skill, female team > female weight; male team > male sprint/skill > male weight, male endurance. ^bModerate and clear-cut differences in training: endurance, weight > team, sprint/skill. ^cModerate and clear-cut differences in eating occasions: endurance > sprint/skill, weight; female weight < all other groups.

Macronutrient intakes reported by athletes were expressed as absolute intakes, intakes relative to BM, and the contribution provided by the macronutrient to total energy intake. Typically, the eating patterns reported by both male and female athletes provided a macronutrient to energy ratio of 55% CHO, 28% fat, 17% protein, and 1% alcohol.

The spread of reported energy intake over various meals and snack times is shown in Figure 1. Overall, the majority of energy was consumed at meals (breakfast: 19% of total reported intake of energy; lunch: 24%; dinner: 34%), with snacks contributing 21% of daily energy intake and 2% of energy being consumed during training sessions. Because of the large variances, differences in the daily spread of energy intake between sexes or groups were typically trivial; however, clear-cut differences are indicated in Figure 1. Figure 2 shows a comparison of the energy and macronutrient intake reported from meals and snacks (including training intake). Meals provided most (>70%) of the daily intake of energy, protein, fat, and CHO, and differences in the relative contribution of these eating occasions to nutrient intake between sports or sexes were trivial due to large variances. There appeared to be large and clear cut differences in the types of foods eaten at meals versus snacks; overall, the foods eaten by athletes at meals provided an energy-to-macronutrient ratio of 50% CHO, 20% protein, and 29% fat, whereas the food consumed as snacks provided an energy-to-macronutrient ratio of 65% CHO, 10% protein, and 22% fat.

Figure 3 summarizing training nutrition practices, shows that athletes typically consumed fluid during 73% of training sessions, with CHO also being consumed at 21% of training sessions. Twenty-seven percent of all training sessions were reportedly undertaken without any intake of food or fluids. Figure 4 shows

Table 3 Daily Intake of Energy and Macronutrients in Sex and Sport Groups

Variable	Sex			Sport			
	All	Female	Male	Endurance	Sprint/skill	Team	Weight
Energy ^a							
MJ	11.1 ± 3.7	9.0 ± 2.5	13.0 ± 3.7	12.7 ± 4.1	10.2 ± 2.7	11.6 ± 4.0	10.1 ± 4.3
KJ/kg	155 ± 47	144 ± 39	166 ± 52	184 ± 52	139 ± 38	157 ± 44	151 ± 47
Macronutrients (%E) ^b							
CHO	54 ± 8	55 ± 8	53 ± 8	60 ± 7	50 ± 8	53 ± 7	55 ± 8
Protein	17 ± 3	18 ± 3	17 ± 3	17 ± 2	18 ± 3	17 ± 3	18 ± 4
Fat	28 ± 8	27 ± 8	29 ± 7	23 ± 7	31 ± 7	29 ± 7	26 ± 9
Alcohol	0.9 ± 1.7	0.8 ± 1.7	1.0 ± 1.8	0.5 ± 1.0	1.0 ± 2.1	1.3 ± 1.8	0.7 ± 1.5
Macronutrients (g) ^c							
CHO	370 ± 140	310 ± 100	420 ± 140	470 ± 150	320 ± 110	370 ± 120	340 ± 130
Protein	117 ± 39	96 ± 26	137 ± 39	129 ± 38	113 ± 33	120 ± 46	108 ± 44
Fat	83 ± 39	64 ± 28	101 ± 38	81 ± 41	83 ± 29	93 ± 42	76 ± 51
Alcohol	3.3 ± 6.5	2.3 ± 4.9	4.2 ± 7.5	2.1 ± 4.6	3.2 ± 6.4	5.8 ± 8.3	2.4 ± 6.3
Macronutrients relative to body mass (g · kg ⁻¹) ^d							
CHO	5.2 ± 1.8	4.9 ± 1.5	5.4 ± 2.1	6.8 ± 2.0	4.4 ± 1.4	5.0 ± 1.3	5.0 ± 1.4
Protein	1.6 ± 0.5	1.5 ± 0.4	1.7 ± 0.5	1.9 ± 0.5	1.5 ± 0.4	1.6 ± 0.5	1.6 ± 0.5
Fat	1.2 ± 0.5	1.0 ± 0.5	1.3 ± 0.5	1.2 ± 0.5	1.1 ± 0.4	1.3 ± 0.6	1.1 ± 0.6

^aAbsolute energy intake (kJ): large and clear-cut differences: males > females; female endurance, female sprint/skill, female team > female weight; male endurance > male sprint/skill, male weight. Relative energy intake (kJ/kg): large and clear-cut difference: male endurance > male weight; moderate differences: males > females. ^bMacronutrient % of E: moderate and clear-cut differences: %CHO: endurance > team, sprint/skill; female team > male team; female weight > male weight; % fat: male weight > female weight; team, sprint/skill > endurance; %alcohol: male team > female team. ^cAbsolute intakes of macronutrients (g): large and clear-cut differences. All nutrients: males > females; CHO intake: endurance > team, sprint/skill, weight; alcohol intake: male team > all other groups. ^dRelative intakes of macronutrients (g/kg): large and clear-cut differences: CHO intake: endurance > team, sprint/skill, weight; alcohol/skill, weight; male endurance > female endurance; fat intake: male endurance > female endurance; male weight > female weight; protein intake: male endurance > female endurance; male weight > female weight. Small-moderate but clear cut differences: all nutrients: males > females.

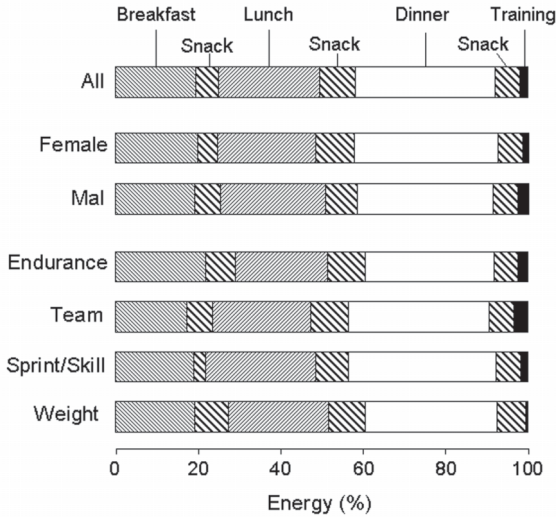


Figure 1 — Proportion of reported daily energy intake consumed at various periods of the day by 167 Australian Olympic athletes. Data are mean values for all athletes and groups of athletes. Standard deviations are breakfast, lunch, and dinner: 7; snacks: 5; training: 3. Clear-cut differences: Breakfast intake: endurance > sprint/skill, team. Dinner intake: sprint/skill, team > endurance. Training intake: males (3%) > females (1%); endurance, team (3%) > weight (0.5); male team (5%) > all other groups.

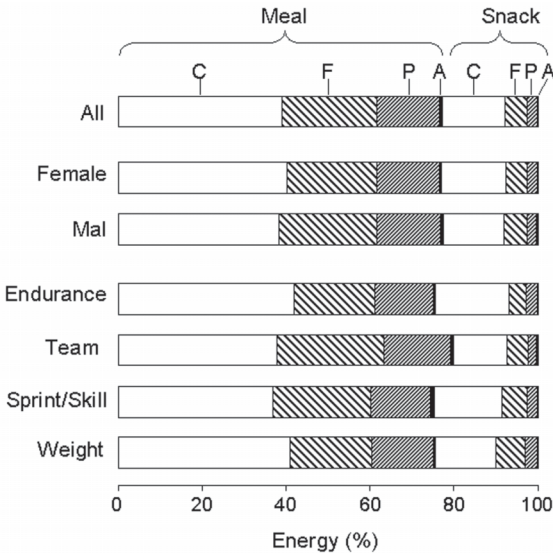


Figure 2 — Proportion of energy from meals and snacks reported by 167 Australian Olympic athletes, provided by carbohydrate (C), fat (F), protein (P), and alcohol (A). Data are mean values for all athletes and groups of athletes. Standard deviations are for meals (C: 8; F: 7; P: 3; A: 1) and snacks (C: 7; F: 4; P: 2; A: 1).

athletes' practices with regard to refueling after training sessions. Overall, athletes achieved the recommended intake of CHO during the first hour after training on 45% of occasions while failing to consume any CHO intake in the first hour after 38% of training sessions. Some CHO was consumed after 17% of training sessions but was insufficient to meet sports nutrition guidelines. Differences between sexes and sporting groups with regard to these practices are noted in the figure legends.

Discussion

This study provides a descriptive account of the dietary patterns of a group of elite Australian athletes in training for the 1996 Olympic Games, including a comparison of the intakes of four separate groups of athletes within this team (endurance, team, sprint/skill, and weight conscious) and gender differences in dietary practices. In addition to providing descriptive accounts of the athletes' reported intakes of energy and macronutrients, we characterized their eating patterns over the day and in relation to their training program. We found differences in apparent intakes of energy and macronutrients according to sport and sex, both in terms of absolute intakes and intakes relative to body mass or total energy intake. We failed to find clear-cut differences between groups in the spread of food over the time course of

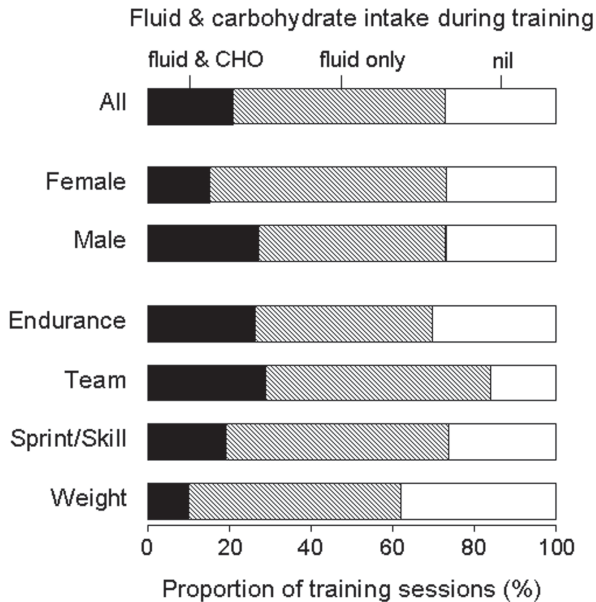


Figure 3 — Proportion of total training sessions undertaken by 167 Australian Olympic athletes at which they reported intake of CHO and fluid, fluid only, or no intake. Data are mean values for all athletes and groups of athletes. Standard deviations are CHO and fluid: 36; fluid only: 30; no intake: 33. Clear-cut differences: *CHO + fluid*: males > females; endurance, team > weight; male team (48% of sessions) > all other groups. *Fluid only*: females < males. *No intake*: endurance, weight > team; male weight (40%) > all other groups.

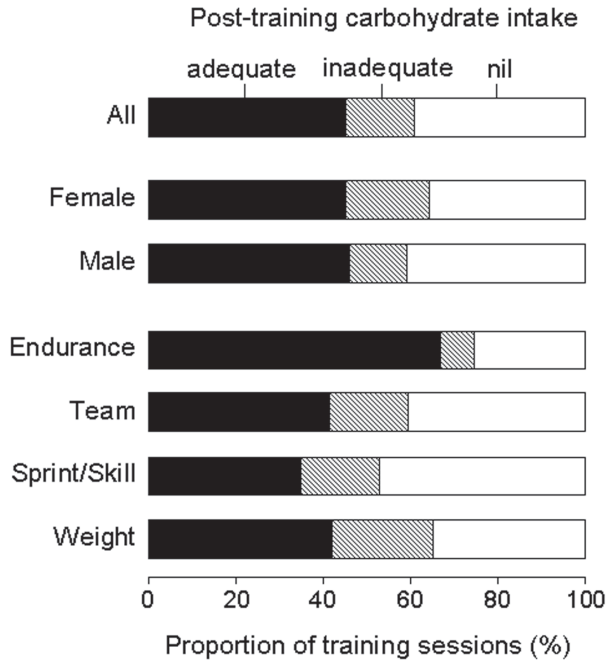


Figure 4— Proportion of total training sessions undertaken by 167 Australian Olympic athletes after which they reported adequate intake of CHO to meet sports nutrition guidelines, inadequate amounts of CHO, or no intake of CHO during the first hour of recovery. Data are mean values for all athletes and groups of athletes. Standard deviations are adequate CHO: 26; inadequate CHO: 17; no CHO: 24. Large and clear-cut differences: *Adequate CHO recovery*: endurance (67% of sessions) > team, sprint/skill, weight. *No CHO intake*: sprint/skill (47%) > endurance, weight; team > endurance.

the day. Typically, athletes reported ~5 separate eating occasions each day, with energy intake consumed from snacks, or between-meal eating occasions, providing ~23% of total energy intake. There was a moderate relationship between total energy intake and the number of separate eating occasions each day, as well as sports-based differences in the number of eating occasions reported each day. There were clear gender- and sport-related differences in dietary practices undertaken during and after exercise, particularly in relation to intake of fluid during exercise, and the intake of CHO during and after sessions. Before we interpret these findings, we will summarize the limitations of dietary survey methodology and the steps we have taken to address these limitations.

Statistics summarizing dietary behavior based on diaries are prone to bias from the mis-reporting of food intake and alterations in behavior during the survey period (4, 5). Reviewers of dietary surveys have concluded that under-reporting of food intake and under-consumption during the survey period are common amongst athletes, especially those who are weight conscious or dissatisfied with their body

image (9, 15). Accuracy improves when athletes are motivated to receive valuable feedback or are trained to enhance their record-keeping skills (9).

This study involved a number of characteristics and intentional measures that help to reduce, or at least standardize the sources of error in our dietary survey tool. First, our athletes were highly motivated individuals who were both accustomed to keeping detailed records related to their sporting preparation, and interested in receiving feedback that might assist their performance. We judged a 7-day diary to be appropriate for such a motivated group, since it would allow us to capture the entire weekly pattern or micro-cycle of the athlete's training program, as well as achieve a substantial decrease in the variability of the estimates of energy and nutrient intake compared with a less demanding 4-day recording period (6). We provided standardized and detailed instructions, both verbally and in writing, to all subjects on how to keep the food diary as accurately as possible.

Second, our protocol of processing the food diaries eliminated the coder error that might otherwise add another substantial source of variability to the estimations of energy and nutrient intake (6). This protocol included crosschecking completed diaries with the athlete, having one coder process all records, using standardized protocols for both quantifying the descriptions of foods and drinks, and finding the item of best fit in the dietary analysis database, and undertaking a standard quality assurance protocol on each record to check for entry errors. We chose to focus on intakes of energy and macronutrients, since these are known to have the lowest daily variability in intake (6, 32).

Many other dietary studies (10, 17, 19, 34, 35) or reviews (7, 9, 20, 21) have provided data on the reported energy and nutrient intakes of elite athletes. The main focus of the present study was to make comparisons of the dietary practices of groups within our athletic population, and specifically to explore the patterns and frequencies of food and fluid intake by elite athletes. Our survey showed clear-cut gender differences in dietary intake. Male athletes reported greater intakes of energy and macronutrients than females with this effect persisting, albeit to a lesser extent, when their greater body mass was taken into account. A gender difference in energy intake, both absolute and relative to body mass, is a common finding of dietary surveys of athletes [for an extensive review of the literature, including a pooling of the results of a large number of studies, see (9)]. Several explanations are possible, and may exist or co-exist in athletic populations; female athletes may undertake a less demanding training program than their male counterparts, they may be more likely to restrict their energy intake in order to achieve low body fat levels, or they may under-report to a greater extent on food records. We did not see a gender difference in the number of training sessions undertaken each week in our study; if anything, female athletes tended to report a greater number of training sessions each week. Of course, we were unable to monitor the energy cost of training in this study.

Within sports, the largest difference in energy intake of female and male athletes relative to body mass occurred in endurance and weight-conscious groups. Although we had classified athletes in weight classification sports (e.g., lightweight rowing, boxing) and aesthetic sports (e.g., gymnastics, diving) as those primarily driven by concern about weight gain, many endurance athletes are also concerned about achieving or maintaining a lean physique to reduce the energy cost of moving their body mass (8). It is well documented that many female athletes in endurance sports, such as distance running and cycling, struggle to achieve their desired level of leanness, despite undertaking a strenuous training program with substantial energy

costs (3, 7). Although males in endurance and weight-conscious sporting groups apparently share the physique goals of their female counterparts, it seems that females carry an additional burden in having a naturally higher body fat level and perhaps, greater societal pressure to achieve an unrealistic body physique. Whether the reported energy intakes of these female athletes denote a greater reliance on energy restriction to achieve physique goals than their male counterparts, or a greater degree of under-reporting due to greater diet-related stress, cannot be determined in this study.

Between sports, endurance athletes reported higher values of energy intake relative to body mass than the other groups, a finding in agreement with the results of other dietary surveys (9) and consistent with the greater number of individual training sessions undertaken by the endurance group compared with team athletes and sprint/skill athletes. Although the weight-conscious athletes reported an equally high number of individual training sessions as endurance athletes, these training sessions were based largely on skill rather than activities with high energy expenditure.

Gender differences in macronutrient intakes, relative to total energy intake or to body mass were trivial, but there were substantial differences between sports. Endurance athletes reported higher intakes of CHO than other groups of athletes (absolute and relative to body mass), in accordance with sports nutrition guidelines (2) and with the findings of other dietary surveys (9). In our study, CHO-rich foods provided a greater proportion of reported energy intake in the diets of endurance athletes (60% of total energy) than in the diets reported by other groups. As a result, the typical male endurance athlete reported a CHO intake (~7.7 g/kg/d) that matched the predicted fuel needs for optimal daily glycogen restoration (7–10 g/kg/d; 9), while the mean daily CHO intake reported by female athletes (~6.2 g/kg) failed to meet this target range principally because of a lower total energy intake. It is likely, however, that these figures are skewed by some level of under-reporting, offering the possibility that the mean *actual* CHO intakes of both groups fell within the recommended range.

We found several other observations of group interactions with dietary choice. Male team athletes in our survey reported the largest intake of alcohol of any athletic group. A relationship between team sports and alcohol use has also been noted in other dietary surveys (10, 35, 36) and reflects both the cultural attitudes and opportunities for group socializing in team sports, as well as the strong link between alcohol and sport that is promoted via sponsorship and advertising. Other findings included the restriction of fat intake by endurance athletes compared with other groups, and female weight-conscious athletes compared with male weight-conscious athletes. The mean reported intake of protein by all groups met or exceeded the recommended intakes for athletes in heavy training (1.2–1.6 g/kg/d; 29), with endurance athletes reporting the highest intake of protein (1.9 g/kg) than all other groups (~1.5–1.6 g/kg), despite consuming diets with a similar protein-to-energy ratio to the other groups.

The timing and frequency of food and fluid intake were a novel aspect of the present study, at least for studies of elite athletes. One of the problems of studying such periodicity of eating is the lack of a standard definition of meals or of eating occasions in general (18). According to two definitions of eating occasion based on intervals between the consumption of food/fluids, the athletes in our survey typically consumed food or drinks on five occasions each day. Other dietary surveys have commented that a pattern of frequent eating is often observed in athletes who achieve a high intake of energy (10, 29, 31). In an earlier study (10) we reported the

typical pattern of 5–6 eating occasions each day by triathletes and runners, while Lindeman (31) studied triathletes who reported a daily average of nine eating occasions. Another survey of runners and cyclists found an average of 8–10 occasions of intake of food/drink per day, with evidence of an inverse relationship between energy intake and the time interval between eating (29). The adoption of a “nibbling” pattern of eating (i.e., consuming a series of small- to moderate-sized meals and snacks over the day) is a logical strategy to increase total energy intake while reducing the gastric discomfort associated with larger meals (29). Indeed, we found a positive relationship between energy intake (kJ/kg) and the number of eating occasions each day for both male and female athletes in our study. However, since the correlation between these factors was only moderate in size, factors other than total energy requirements are also important in dictating the number of eating occasions each day—for example, cultural patterns, food availability, and the schedule of daily activities (13).

We were interested to see if gender and sport per se provided a substantial influence on the spread of energy intake over the time-course of day by dividing the 24 h into 6 categories based on time cues, with a separate category for training sessions. We found that variability of energy spread within each group prevented many differences between groups from being detected as clear-cut. Nevertheless, there was evidence that endurance athletes consumed a greater proportion of their daily energy intake in the morning (i.e., the breakfast meal) than athletes in team sports and sprint/skill events. These latter groups subsequently consumed a proportionally larger meal at dinner.

The only other study of dietary periodicity of athletes is a dietary survey undertaken by Butterworth and colleagues (11) of a group of runners training in preparation for the 1987 Los Angeles Marathon. In planning the present study, we had intended to use the timing system designed by Butterworth et al (11), to enable a direct comparison of the results of the two investigations. However, we found their coding system misrepresented the pattern of meals and snacks eaten by our athletes. Whereas the marathon study investigated a large number of dedicated but recreational athletes whose training and eating patterns were organized around their work schedules, our sample involved elite and “professional” athletes whose training schedule was their main occupation. Our need for a customized timing code that reflected the unique pattern of daily activities of our subjects provides confirmation of the difficulties of studying the periodicity of eating in free-living groups (13).

According to the definitions used in our study, we found that ~23% of the total energy intake reported by our athletes was provided by “snacks” (foods/drinks consumed outside the periods we designated to be main meal times). Other surveys of athletes using different methodologies have estimated that the contribution of “between meal snacks” was 25–37% of the total daily energy intake (11, 14, 28, 35). We are aware of the criticism that the labeling of eating occasions into “meals” or “snacks” is often arbitrary or value-laden (18); however, our data are consistent with a substantial difference in the foods chosen by athletes to consume on these occasions. Snacks were more likely to be chosen from foods that are CHO-rich, and lower in protein and fat content than foods eaten at breakfast, lunch, and dinner. This difference may have arisen because snacks are often eaten away from the home or in transit between locations or activities, or because snacks are specifically chosen to address the preparation and recovery needs of training sessions.

We described the direct intake of foods/drinks in relation to training sessions in a number of ways. When considering the spread of energy over the day, we found

that endurance and team athletes, particularly males, reported consuming a greater proportion of their daily energy intake *during* exercise sessions than sprint/skill and weight-conscious groups. It is likely that these athletes are aware of the benefits of consuming CHO to provide a supplementary fuel source for the muscle and central nervous system during prolonged sessions of moderate or intermittent high intensity exercise (22). The practice of consuming a significant amount of the day's total energy and nutrient intake while undertaking exercise has been most obvious in studies of cyclists undertaking stage races (33). In such cases, athletes must not only provide substrate for the immediate exercise session but, in the face of extremely high energy requirements, must use all available "waking hours" to consume their daily needs, including the 6–10 h of daily exercise. For example, CHO-rich foods and drinks consumed during each day's stage have been reported to provide nearly 50% of the total daily energy and 60% of the daily CHO intake of Tour de France cyclists, and enabled them to maintain remarkable energy balance over 3 weeks and 2000 km of cycling (33). By comparison, in our study, male team and endurance athletes reported consuming ~3–5% of their total energy intake, during training sessions.

We also examined each training session undertaken by athletes in terms of fluid and CHO intake during exercise, and the consumption of CHO during the post-exercise phase to achieve rapid recovery of glycogen stores (27). We found that over a quarter of the training sessions undertaken by both males and females during the period of recording were completed without any intake of fluid or CHO, in contradiction to the general guidelines for good sports nutrition practice (1, 2). Although it is hard to generalize about the specific nutritional requirements of training sessions across sports, it is likely that the sessions undertaken by team and endurance athletes are the most nutritionally demanding, and would benefit from both fuel and fluid replacement. In our study, team athletes appeared to be more organized in replacing fluids and CHO during training sessions than endurance athletes, perhaps because the provision of centralized and supervised supplies of sports drinks has become a feature of the group training sessions undertaken by many team sports. Although endurance athletes reported that many training sessions were undertaken without any nutritional support, when nutritional strategies were undertaken, they were more likely to involve CHO replacement rather than fluid alone.

Overall, although males and females were equally likely to consume foods and drinks during the training session, males were twice as likely as females to consume CHO along with fluid, whereas females were more likely to consume water alone, and weight conscious athletes were both less likely to consume any fluid or food during a training session, and less likely to consume CHO if any nutritional support was undertaken, than any other athletic group. This may be because training sessions were less likely to require nutritional support (i.e., to promote sweat losses or utilization of muscle glycogen stores). But it may also be due to the reluctance of these athletes to consume energy that they consider unnecessary, or their satisfaction at seeing a reduction in body mass at the end of the session, even though it reflects dehydration rather than true loss of body fat.

Finally, it appears that endurance athletes were not only successful in meeting the CHO intakes promoted for daily refueling, but were also more successful than other groups in promoting rapid recovery after each training session by consuming substantial CHO intakes within the first hour post-exercise to optimize muscle glycogen resynthesis (27). Of course, it is most likely that these athletes experienced training conditions that were most deserving of rapid refueling (i.e., glycogen depleting exercise, more than one session per day). However athletes involved in other

sporting groups, particularly team sports, may also under training situations that are equally fuel demanding on at least some occasions. Overall, athletes were almost equally spread between achieving CHO intakes for optimal refueling after exercise, and failing to refuel at all during the first hour of recovery, and there were no gender differences in attention to this nutrition guideline.

In summary, we found differences in the dietary patterns reported by elite athletes who were in training for the 1996 Olympic Games, both as a result of gender and type of sporting activity. Although the typical eating patterns of some of the groups of athletes met many of the literature guidelines for sports nutrition, other practices were suboptimal. Although it is difficult to study the periodicity of eating, because of a lack of standardization of methodology, information of this type is interesting in understanding how athletes can best meet their total energy needs, and promote fuel availability for training sessions.

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