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ORIGINAL RESEARCH

# Dietitian-Observed Macronutrient Intakes of Young Skill and Team-Sport Athletes: Adequacy of Pre, During, and Postexercise Nutrition

**Lindsay B. Baker, Lisa E. Heaton, Ryan P. Nuccio, and Kimberly W. Stein**

***Context***: Sports nutrition experts recommend that team-sport athletes participating in intermittent high-intensity exercise for ≥1 hr consume 1–4 g carbohydrate/kg 1–4 hr before, 30–60 g carbohydrate/hr during, and 1–1.2 g carbohydrate/kg/hr and 20–25 g protein as soon as possible after exercise. The study objective was to compare observed vs. recommended macronutrient intake of competitive athletes under free-living conditions. ***Methods***: The dietary intake of 29 skill/team-sport athletes (14–19 y; 22 male, 7 female) was observed at a sports training facility by trained registered dietitians for one 24-hr period. Dietitians accompanied subjects to the cafeteria and field/court to record their food and fluid intake during meals and practices/competitions. Other dietary intake within the 24-hr period (e.g., snacks during class) was accounted for by having the subject take a picture of the food/fluid and completing a log. ***Results***: For male and female athletes, respectively, the mean ± *SD* (and percent of athletes meeting recommended) macronutrient intake around exercise was 1.4 ± 0.6 (73%) and 1.4 ± 1.0 (57%) g carbohydrate/kg in the 4 hr before exercise, 21.1 ± 17.2 (18%) and 18.6 ± 13.2 (29%) g carbohydrate/hrr during exercise, 1.4 ± 1.1 (68%) and 0.9 ± 1.0 (43%) g carbohydrate/kg and 45.2 ± 36.9 (73%) and 18.0 ± 21.2 (43%) g protein in the 1 hr after exercise. ***Conclusion***: The male athletes' carbohydrate and protein intake more closely approximated recommendations overall than that of the female athletes. The most common shortfall was carbohydrate intake during exercise, as only 18% of male and 29% of female athletes consumed 30–60 g carbohydrate/hr during practice/competition.

***Keywords:*** adolescents, carbohydrate, protein, 24-hr energy intake, energy expenditure, dietary observations

Good nutrition practices are one of many important behaviors that can lead to successful sports performance (American Dietetic Association et al., 2009). While specific physiological demands may vary among sports (e.g., frequency of games, length of season, position-specific requirements), one common feature is the "stop-and-go" nature of team sports, with high intensity bursts interspersed with periods of lower intensity activity or rest periods. Based on this pattern, most team-sport athletes use a combination of anaerobic and aerobic energy systems, both of which rely on carbohydrate as the primary fuel source (Holway & Spriet, 2011). To this end, sports nutrition experts recommend that team-sport athletes participating in intermittent high-intensity training or competition for ≥ 1 hr ingest 30–60 g of carbohydrate every hour of exercise (American Dietetic Association et al., 2009; Burke et al., 2011; Holway & Spriet, 2011) to provide fuel to the muscle and central nervous system (Burke et al., 2011). In addition, eating before a practice or game replenishes liver glycogen stores, especially if the workout or competition is in the morning. Thus, it is recommended that a preevent meal be eaten ~1–4 hr before exercise and contain ~1–4 g carbohydrate/kg (Burke et al., 2011). Restoring the carbohydrate used from the muscle and liver during both aerobic and anaerobic-type activity is an important postexercise nutrition practice for team-sport athletes. When athletes have less than 8 hr between practices or competitions, 1.0–1.2 g carbohydrate/kg should be consumed every hour for 4 hr (Burke et al., 2011). In addition, it is recommended that most team-sport athletes consume about 20–25 g of protein to start the recovery process as soon as possible after each training session and game to maximize muscle protein synthesis (Phillips & van Loon, 2011). To meet daily macronutrient needs, sports nutrition experts recommend team-sport athletes consume 5–7 g carbohydrate/kg/day and 1.2–1.7 g protein/kg/day (American Dietetic Association et al., 2009; Holway & Spriet, 2011).

Given the impact that pre, during-, and postexercise carbohydrate and/or protein intake may play in maintaining athletic performance (Akermark et al., 1996; Balsom et al., 1999; Cockburn et al., 2010; Dougherty et al., 2006; Phillips et al., 2010; Rowlands et al., 2008), it would be interesting to determine whether athletes actually meet these recommendations. While several studies have described the 24-hr energy and macronutrient intake of

The authors are with the Gatorade Sports Science Institute, Barrington, IL. Address author correspondence to Lindsay B. Baker at lindsay.baker@pepsico.com.

stop-and-go athletes (Holway & Spriet, 2011), relatively few have involved youth (Beals, 2002; de Sousa et al., 2008; Gibson et al., 2011; Heaney et al., 2010; Juzwiak et al., 2008; Papadopoulou et al. 2002; Rico-Sanz et al., 1998), and none have employed direct observations by dietitians or quantified their acute intake around the active occasion, i.e., 1–4 hr before, during, and 1 hr after exercise. It would be useful to identify common sports nutrition shortfalls among competitive athletes so that education can be targeted to appropriate nutrients and occasions (i.e., pre, during, and/or postexercise). Because previous studies have shown that many individuals, including adolescents and athletes, are inaccurate at estimating energy intake when self-recording or recalling their diet (Hill & Davies, 2001), we felt it critical to have registered dietitians observe the subjects' dietary intake. Furthermore, direct observation of meals is more accurate than recall methods because it is not dependent on the subjects' memory. In fact, observations are often used as the gold standard method by which dietary assessment tools are validated in studies with children and adolescents (McPherson et al., 2000; Mertz, 1992; Rumbold et al., 2011; Smith et al., 2007). Therefore, the aim of the current study was to have trained dietitians observe the 24-hr dietary intake of 14- to 19-year-old highly active, competitive skill/team-sport athletes under free-living conditions and compare macronutrient intake to that recommended before, during, and after practice/competition as well as in a 24-hr period.

It is important to note that the sports nutrition recommendations outlined above are largely extrapolated from research with adults. While there may be some differences in exercise metabolism and substrate utilization between adults and prepubertal children (~8–13 years), adult-child differences are thought to lessen as children mature (Riddell, 2008). At this time, no separate sports nutrition recommendations are available for young athletes. Therefore, for the purpose of this study with 14- to 19-year-old athletes, we compared intake to the available carbohydrate and protein recommendations for adult team sport athletes.

# Methods

## Subjects and Recruitment

A total of 39 competitive athletes (29 male, 10 female) between 14 and 19 years of age were originally recruited for participation in the study. Participants and their parent/guardian were informed of the experimental procedures and associated risks before providing written informed consent. This study was approved by the Sterling Institutional Review Board (Atlanta, GA) for the protection of human subjects. To be eligible to take part in this study, subjects had to be participating in sports on the scholastic, collegiate, or amateur/professional/elite level. Subjects were recruited via e-mail and flyer announcements to all athletes living and training at a sports training facility (details provided in Testing Site section). The subjects competed in soccer, tennis, basketball, football, golf, lacrosse, or baseball. Criteria for exclusion were extreme dietary habits, eating disorders (assessed by the SCOFF clinical prediction questions; Cotton et al., 2003), and current infection. None of the volunteers were deemed at risk for having an eating disorder or reported losing >6.4 kg in the past three months according to answers provided on the SCOFF questionnaire. However, upon completion of the dietary observations it was apparent that one female athlete was intentionally restricting energy intake to lose weight, thus her data were not included in the study. In addition, nine subjects (7 male, 2 female) data were excluded from analysis due to noncompliance (details provided in Quality Control section). Thus, a total of 29 (22 male, 7 female) out of the original 39 athletes recruited were included in the final descriptive analysis. Subject characteristics of the athletes that completed the study are presented in Table 1. The ethnic makeup of the subjects was 66% not Hispanic or Latino and 34% Hispanic or Latino and the racial makeup was 73% Caucasian, 14% African American, 3% Asian, and 10% multiracial. On the day of dietary observations, subjects were active for a total of 2.9 ± 1.1 hr and 3.2 ± 1.2 hr for male and females, respectively. The athletes' activity involved intermittent moderate- to high-intensity exercise and skill work during practices/competition as well as aerobic conditioning and/or resistance training (a breakdown by sport is provided in Table 2). During the time of this study, tennis athletes were in-season competing in matches while all other sports were in off-season training.

## Testing Site

Data collection took place at the Gatorade Sports Science Institute at IMG Academies in Bradenton, FL over a 6 week period in the months of April and May. The IMG Academies is a sports training facility where young athletes live, train for and compete in their sport, and go to school during the academic year. Because these

**Table 1 Subject Characteristics**

| | *n* | Duration of Activity* (hr) | Age (yr) | Body Mass (kg) | Height (cm) |
|---|---|---|---|---|---|
| Male | 22 | 2.9 ± 1.1 | 17 ± 2 | 74.0 ± 11.9 | 178.2 ± 9.1 |
| Female | 7 | 3.2 ± 1.2 | 16 ± 2 | 62.3 ± 6.8 | 167.8 ± 3.0 |

*Note*. Values are means ± SD. *Duration of activity was the amount of time the athletes were active, including practice/competition on the field/court, aerobic conditioning, and resistance training on the day they were being observed by dietitians. The activities were completed back-to-back in the morning or afternoon with short transitions (~10-20 min) between types of activity.

**Table 2 Breakdown of Subjects, Activity Duration/Type, and Adequacy of Carbohydrate and Protein Intake by Sport**

| | | | | % of Athletes that had Adequate Intake[a] | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sport** | ***n*** | **Total Activity Duration (hr)** | **Description of Activity (including % of time spent in each activity)** | **24-hr CHO** | **24-hr Protein** | **Pre-exercise CHO** | **During exercise CHO** | **Postexercise CHO** | **Postexercise Protein** |
| Soccer | 7 M, 3 F | 3.0 ± 1.1 | 57% on-field practice, 32% weight-training, 11% aerobic conditioning | 80% | 90% | 80% | 20% | 90% | 100% |
| Basket-ball | 7 M, 1 F | 2.7 ± 1.4 | 57% on-court practice, 30% weight-training, 13% aerobic conditioning | 75% | 100% | 63% | 13% | 38% | 38% |
| Tennis | 3 M, 3 F | 3.2 ± 1.1 | 90% matches, 10% aerobic conditioning | 67% | 100% | 67% | 33% | 67% | 83% |
| Lacrosse | 2 M | 2.8 ± 1.1 | 60% on-field prac-tice, 20% weight training, 20% aerobic conditioning | 100% | 100% | 50% | 50% | 50% | 100% |
| Golf | 1 M | 3.5 | 100% practice on golf course/ driving range | no | yes | yes | no | no | no |
| Football | 1 M | 2 | 100% on-field practice | yes | yes | yes | no | no | no |
| Baseball | 1 M | 3.5 | 71% on-field practice, 19% weight training | yes | no | no | no | yes | yes |

*Note*. Duration of activity was the amount of time the athletes were active, including practice/competition on the field/court, aerobic conditioning, and resistance training on the day they were being observed by dietitians. The activities were completed back-to-back in the morning or afternoon with short transitions (~10–20 min) between types of activity. CHO = carbohydrate; F = female; M = male; pre-exercise = consumed in the 4 hr before exercise; postexercise = consumed in the 1 hr after exercise.

[a]The percent of athletes whose dietary intake met or exceeded recommended amounts.

athletes generally stayed on campus all day it enabled the researchers to observe food/drink intake for a 24-hr period. We observed at least one athlete from each skill/team sport (see Table 2) represented at the sports training facility. The distribution of subjects from the various sports represented in the study was also similar to the distribution at the training facility.

## Dietary Observations

To determine what the subjects ate in a 24-hr period their dietary intake was observed and recorded. Observations were completed by 3 trained registered dietitians. Each dietitian observed 1–2 subjects at a time. The subjects were aware that their dietary intake was being recorded; however, they were blinded to the main objective of the study to assess their pre, during, and postexercise carbohydrate/protein intake. Furthermore, subjects were asked to consume their usual diet on the day of observations. All dietitians were trained on how to observe and document the subjects' dietary intake. Observers had access to the kitchen and kitchen staff to obtain relevant information (e.g., composition, brand names, and preparation details) about the food/drinks served in the IMG Academies cafeterias.

On the day of the observations, subjects reported to the laboratory in the morning before eating breakfast (~6:00am). Then, a dietitian followed the subject throughout the day and observed their dietary intake from breakfast through dinner (~6:00pm). This involved sitting with the subjects in the cafeteria during breakfast, lunch, and dinner, as well as attending the subjects practices/games to observe and record their entire dietary intake, including sports nutrition products and supplements. Athletes at the IMG Academies routinely had access to both water and a 6% carbohydrate sports drink during practices and games. The dietitians recorded the type and amount of foods and drinks consumed on a standardized observer's log. Dietitians did not comment or give the athletes feedback about their dietary intake so as not to affect the athletes' food/drink choices. To avoid being overly intrusive, portion sizes were estimated by visual observations only (no measuring spoons/cups or scales were used). In addition, dietary intake was not observed while the subjects were in their class, locker room, or dorm. Therefore, the subjects were asked to take a picture of and complete a food log for any snacks or drinks consumed when they were not being observed by a dietitian. The athletes were each given a 3 inch by 3 inch notecard with their subject number to include in the picture (for scale and identification purposes). For supplements and prepackaged snacks/drinks, subjects were also asked to take a picture or turn in the nutrition facts label. The information from the dietitians' logs and the subjects' logs/pictures was entered into NutriBase (CyberSoft, Inc., Phoenix, AZ) to determine the subjects' energy and macronutrient intake for the 24-hr period (from the time the subject woke up on one day to the time they woke up on the next day).

## Quality Control

The dietitians' interobserver reliability (IOR) was measured at least once per week throughout the duration of the study. To determine IOR two dietitians simultaneously observed the meals and practices of one subject throughout the course of the day. IOR was calculated as the percent of matches [(matches/total number of items observed) × 100] between the dietitians over the course of one 24-hr period of observations. An item was considered a match when the dietitians' estimations of the amount of food or fluid consumed agreed within one-quarter of a serving (e.g., within 60 mL for fluid and within 20 g for meat). Results from IOR on 9 subjects indicated 88% mean agreement (median = 87%, minimum = 74%, maximum = 100%) across observers, which is considered acceptable (Baglio et al., 2004). When two dietitians observed an athlete's dietary intake, the data used in the descriptive analysis was from the "main" observer, which was designated before observations. The data obtained by the second observer was used only for calculating IOR.

As another measure of quality control, subject compliance (following instructions to inform us about snacks consumed when not with the dietitian) was monitored closely to determine if an observation was incomplete. If a subject failed to follow-up with the dietitian to report any snacking (i.e., did not turn in food log/pictures and did not return follow-up phone calls) their observation data were deemed invalid/incomplete and not included in the final data set. In total, 9 athletes (4 male soccer, 1 female soccer, 2 male tennis, 1 female tennis, and 1 male football player) out of the 39 subjects originally enrolled for observations failed to comply with study instructions.

## Energy Expenditure

The athletes resting metabolic rate was estimated using the Harris-Benedict equation (Harris & Benedict, 1919) and exercise energy expenditure was estimated using the subjects' body mass, activity type, and activity duration, according to the tables of McArdle et al., (2004). For exercise activities not found in the McArdle et al. (2004) tables, or for subjects with a body mass outside of the ranges in these tables, metabolic equivalents (METs) were used as an estimate of exercise energy expenditure (Ainsworth et al., 2011). Total energy expenditure was determined by adding resting and exercise energy expenditure during the 24-hr period.

## Statistical Methods

Statistical analyses were performed using SPSS (version 15.0.1, IBM, Armonk, NY). Central tendency and dispersion of the data are described using the mean, standard deviation, and 95% confidence interval of the mean. Differences between energy intake and expenditure were assessed using the correlated-measures *t*-test. The single-sample *t* test was used to compare means with the lower and upper bounds of nutritional recommendations for carbohydrate and protein intake. All *t* tests were one-tailed because we hypothesized that athletes would consume more than the recommended amount for protein (especially the males), less than the recommended amount for carbohydrate, and less than that of energy expenditure (especially the females). Statistical significance was assessed at alpha <0.05. The percent of athletes with adequate carbohydrate and protein intake (equal to or exceeding the lower bound of the recommended range) was also calculated. Histograms are presented for all dependent measures (along with lower and upper recommended bounds) visually summarizing 100% of the data to facilitate graphical analysis and interpretation. No data transformations have been employed. Separate analyses were conducted for male and female athletes.

# Results

## By Sport

Table 2 provides a breakdown by sport of subjects' activity duration/type and adequacy of 24-hr and pre, during, and postexercise carbohydrate/protein intake. The energy intake vs. energy expenditure for sports in training (in which more than two study subjects participated) was 4164 ± 1507 kcal vs. 3738 ± 828 kcal ($p$ = .57, ES = 0.36) and 2912 ± 700 kcal vs. 3300 ± 922 kcal ($p$ = .23, ES = 0.48) for basketball and soccer, respectively. Tennis players were in competition during observations and consumed 2678 ± 954 kcal vs. 4107 ± 884 kcal energy expenditure ($p$ = .12, ES = 1.09).

## By Sex

Table 3 shows a comparison of the observed 24-hr energy intake vs. the estimated 24-hr energy expended for the male and female athletes. The mean difference between intake and expenditure was not statistically significant for the male or female athletes. Female athletes observed on competition days (tennis matches) consumed 2037 ± 13 kcal vs. 3894 ± 840 kcal energy expenditure. Female athletes observed on training days (soccer and basketball) consumed 2267 ± 552 kcal vs. 3103 ± 1008 kcal energy expenditure. Male athletes observed on competition days (tennis matches) consumed 3320 ± 1019 kcal vs. 4320 ± 1055 kcal energy expenditure. Male athletes observed on training days (soccer and basketball) consumed 3595 ± 1179 kcal vs. 3642 ± 838 kcal energy expenditure.

Table 4 shows the observed vs. recommended macronutrient intake of the male and female athletes. Most (>50%) of the male athletes consumed adequate macronutrients for 24-hr carbohydrate and protein, preexercise carbohydrate, and postexercise carbohydrate and protein. In addition, according to the single-sample *t* test results, their observed intakes were significantly ($p < .05$) greater than the lower bound of the recommended ranges for 24-hr carbohydrate and protein, preexercise carbohydrate, and postexercise protein. The male athletes mean intake was also significantly ($p < .05$) higher than the upper bounds of the recommended ranges for 24-hr protein and postexercise protein intake. The only categories in which most (>50%) of the female athletes met the recommended intake was 24-hr protein and preexercise carbohydrate.

There was a shortfall in carbohydrate intake during exercise for both sexes, as only 18% of male and 29% of female athletes consumed 30–60 g carbohydrate/hr during practice or competition. In addition, according to the single-sample *t* test, the observed carbohydrate intake during exercise was significantly less than 30 g/h for male ($p = .024$) and approached statistical significance for female ($p = .062$) athletes.

Figures 1 and 2 are histograms showing the carbohydrate intake (24-hr, preexercise, during exercise, and postexercise) by the female and male athletes, respectively. The histograms in Figures 3 and 4 show the protein intake (24-hr and postexercise) by the female and male athletes, respectively.

**Table 3 Energy Intake vs. Energy Expenditure**

| | 24-hr Energy Expenditure (kcal) | 24-hr Energy Intake (kcal) | Mean Difference (kcal with 95% CI, 1-tailed) | *p*-value |
|---|---|---|---|---|
| Male athletes (*n* = 22) | 3791 ± 870 | 3522 ± 1137 | –269 (-831) | .419 |
| Female athletes (*n* = 7) | 3311 ± 1092 | 2299 ± 495 | –1012 (-2055) | .108 |

*Note*. Energy intake and expenditure values are means ± SD. Mean differences are reported with 95% CI, 1-tailed test (only the lower boundary is reported).

**Table 4 Macronutrient Intake vs. Recommendations**

| | Male Athletes (*n* = 22) | | | | |
|---|---|---|---|---|---|
| | Recommended Range | Mean (95% CI) | % of Athletes that had Adequate Intake[a] | *p*-value vs. Lower End of Recommended Range | *p*-value vs. Upper End of Recommended Range |
| 24-hr CHO (g/kg) | 5–7 | 6.7 (5.7–7.6) | 82% | **.001** | .440 |
| 24-hr Protein (g/kg) | 1.2–1.7 | 2.3 (2.0–2.6) | 100% | **.000** | **.001** |
| Pre-Exercise CHO (g/kg) | 1–4 | 1.4 (1.1–1.6) | 73% | **.016** | ***.000*** |
| During Exercise CHO (g/h) | 30–60 | 21.1 (13.5–28.7) | 18% | ***.024*** | ***.000*** |
| Postexercise CHO (g/kg) | 1.0–1.2 | 1.4 (0.9–1.9) | 68% | .091 | .381 |
| Postexercise Protein (g) | 20–25 | 45.2 (28.9–61.6) | 73% | **.004** | **.018** |
| | Female Athletes (*n* = 7) | | | | |
| 24-hr CHO (g/kg) | 5–7 | 5.7 (4.0–7.4) | 43% | 0.377 | .103 |
| 24-hr Protein (g/kg) | 1.2–1.7 | 1.4 (1.1–1.7) | 86% | 0.130 | ***.047*** |
| Pre-Exercise CHO (g/kg) | 1–4 | 1.4 (0.5–2.3) | 57% | 0.321 | ***.000*** |
| During Exercise CHO (g/h) | 30–60 | 18.6 (6.3–30.8) | 29% | 0.062 | ***.000*** |
| Postexercise CHO (g/kg) | 1.0–1.2 | 0.9 (0.0–1.9) | 43% | 0.854 | .503 |
| Postexercise Protein (g) | 20–25 | 18.0 (0.0–37.5) | 43% | 0.808 | .413 |

*Note*. Text in ***bold italics*** indicates where macronutrient intake is significantly ($p < .05$) less than and text in **bold** indicates where intake is significantly ($p < .05$) greater than recommended intake at the upper or lower end of the ranges as indicated (one-tailed single-sample *t*-test). CHO = carbohydrate; pre-exercise = consumed in the 4 hr prior to exercise; postexercise = consumed in the 1 hr after exercise.

[a]The percent of athletes whose dietary intake met or exceeded recommended amounts.

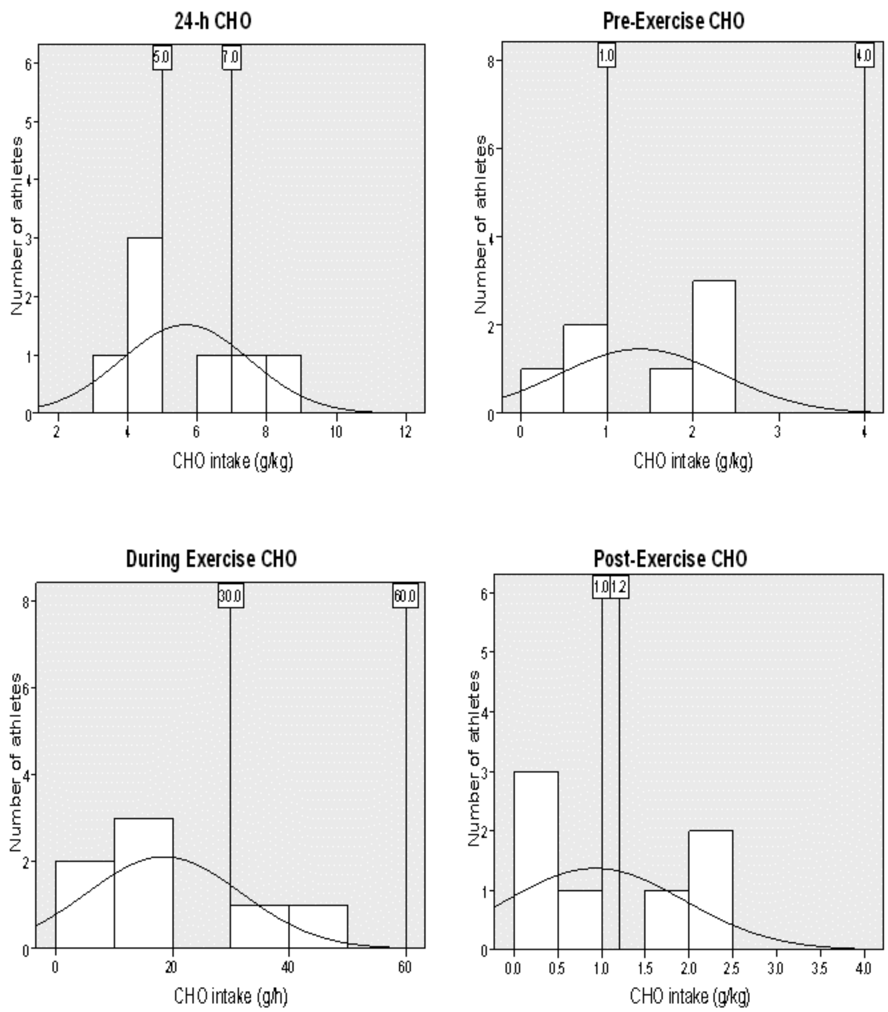


**Figure 1** — Histograms showing carbohydrate intake by 7 female team-sport athletes in a 24-hr period, in the 4 hr before exercise, during exercise, and in the 1 hr after exercise. Each histogram shows the distribution of the subjects' intake and is fitted with a normal curve for comparison with recommendations. Lower and upper bounds of the recommended ranges are shown with vertical lines (5–7 g carbohydrate/kg/day, 1–4 g carbohydrate/kg before exercise, 30–60 g carbohydrate/hr during, and 1–1.2 g carbohydrate/kg after exercise). CHO, carbohydrate

## Discussion

In this study registered dietitians directly observed the 24-hr dietary intake of young, highly active, competitive skill and team-sport athletes to determine the adequacy of their pre, during, and postexercise nutrition. The main finding was that the most common macronutrient shortfall was carbohydrate during exercise, as only 18% of male and 29% of female athletes consumed 30–60 g carbohydrate/hr during practice/competition. Another finding was that there were sex differences in the observed vs. recommended macronutrient intake and observed energy intake vs. energy expenditure, with male athletes' carbohydrate fueling and carbohydrate/protein recovery nutrition being more adequate overall than the female athletes. Furthermore, male athletes consumed significantly more protein than recommended post exercise and in a 24-hr period.

Many energy/dietary intake assessment techniques exist, including food frequency questionnaires, self-reported food records, dietary recall interviews, direct observation, and doubly-labeled water techniques. We chose to employ direct observations as our primary dietary assessment method to avoid dependence on the subject's memory and ability to estimate portion size. In addition, because we wanted to assess what free-living athletes consumed in a sporting context (as opposed to under laboratory conditions) we chose observations to limit invasiveness, distraction, and subjects' time commitment to participate in the study. It would be impractical to ask subjects to weigh and record their food and fluid intake during training or competition. Overall, the aim in using observations in this study was to use the expertise of trained dietitians rather than putting the onus on the athletes to record or remember their food and fluid intake.

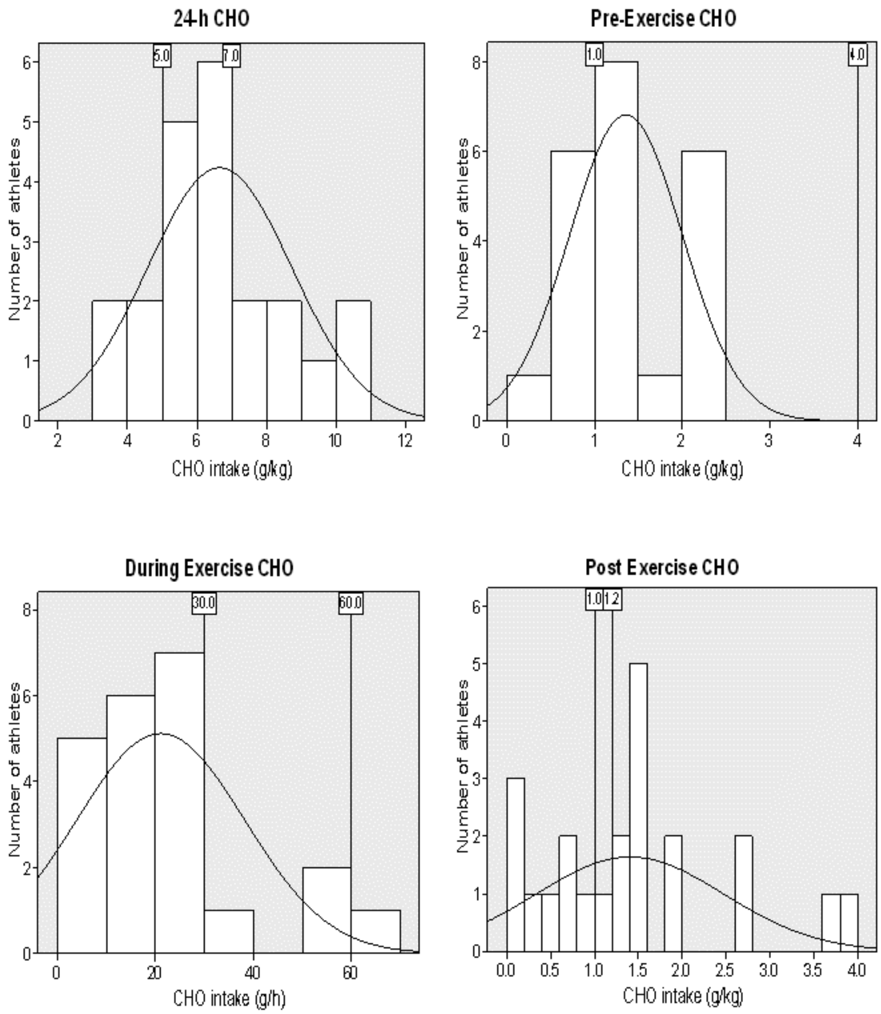


**Figure 2** — Histograms showing carbohydrate intake by 22 male team-sport athletes in a 24-hr period, in the 4 hr before exercise, during exercise, and in the 1 hr after exercise. Each histogram shows the distribution of the subjects' intake and is fitted with a normal curve for comparison with recommendations. Lower and upper bounds of the recommended ranges are shown with vertical lines (5–7 g carbohydrate/kg/day, 1–4 g carbohydrate/kg before exercise, 30–60 g carbohydrate/hr during, and 1–1.2 g carbohydrate/kg after exercise). CHO, carbohydrate.

The most novel aspect of our study was the dietitian-observed nutrient intake of team-sport athletes before, during, and after practice/competition. Previous studies have monitored voluntary fluid intake for purposes of gauging hydration habits and the prevalence of dehydration (Decher et al., 2008; Kavouras et al., 2012), but it is also important to understand the appropriateness of athletes' fueling behaviors around the active occasion. For pre- and postexercise nutrient intake, we found that male athletes consumed adequate carbohydrate and protein. In female athletes, there were no statistically significant differences between observed intake and the lower bound for each pre- and postexercise recommendation, but in most cases less than 50% of females consumed adequate quantity of nutrients. It is worth noting that these athletes had access to a variety of foods/drinks in cafeterias, thus energy/nutrient availability was not an issue. Overall, most of the athletes that met postexercise recommendations (16 out of 19) did so by consuming a meal after exercise, while only a few (3 out of 19) did so by eating a postexercise snack.

The most common shortfall across both sexes was inadequate carbohydrate intake during exercise. Most (>50%) of the male and female athletes consumed less than 30 g carbohydrate per hour. Overall, the athletes in the current study consumed more adequate nutrition (carbohydrate and/or protein) with meals before/after activity than they did ingesting carbohydrate during exercise. Although preexercise carbohydrate is an important component of sports nutrition, athletes still need exogenous carbohydrate during exercise to meet energy demands and support performance (Febbraio et al., 2000). Carbohydrate feedings during exercise have been shown to delay fatigue and improve performance during prolonged continuous exercise as well as intermittent high-intensity activity (Burke et al., 2011). In fact,

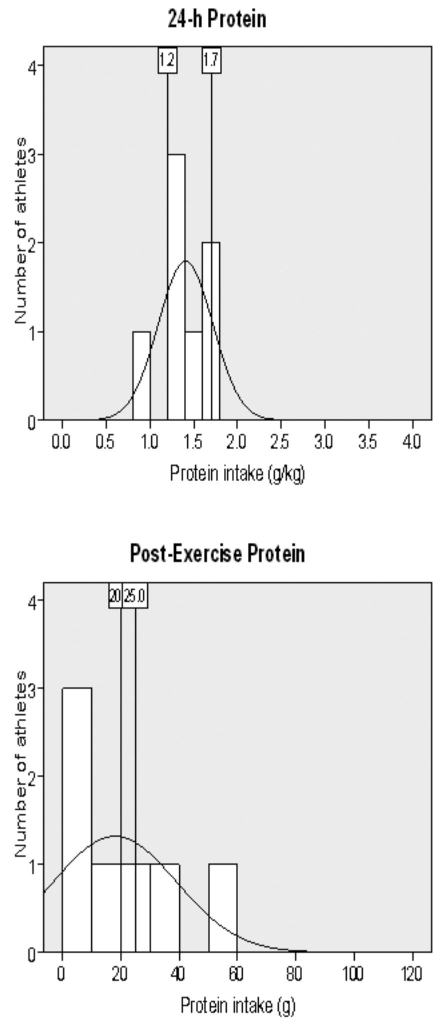


**Figure 3** — Histograms showing protein intake by 7 female team-sport athletes in a 24-hr period and in the 1 hr after exercise. Each histogram shows the distribution of the subjects' intake and is fitted with a normal curve for comparison with recommendations. Lower and upper bounds of the recommended ranges are shown with vertical lines (1.2–1.7 g protein/kg/day and 20–25 g protein after exercise).

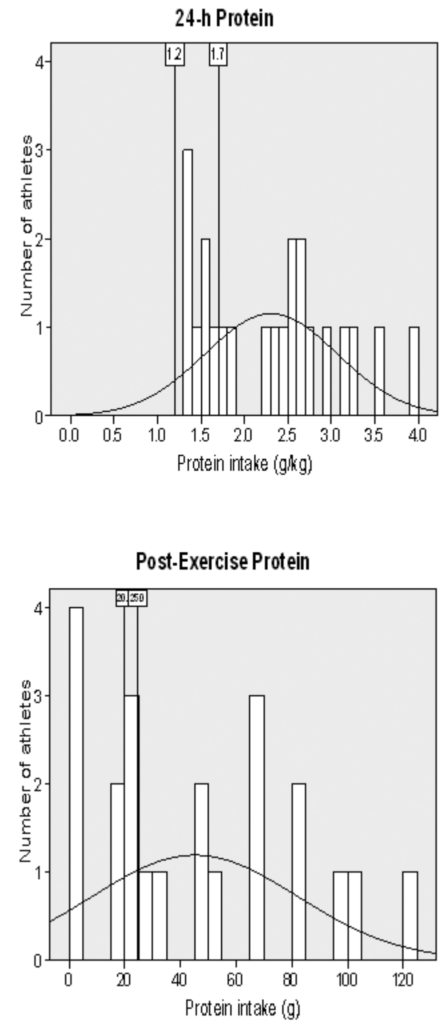


**Figure 4** — Histograms showing protein intake by 22 male team-sport athletes in a 24-hr period and in the 1 hr after exercise. Each histogram shows the distribution of the subjects' intake and is fitted with a normal curve for comparison with recommendations. Lower and upper bounds of the recommended ranges are shown with vertical lines (1.2–1.7 g protein/kg/day and 20–25 g protein after exercise).

studies with adolescent athletes have found that carbohydrate intake during team sport-type activities can improve endurance capacity during intermittent high-intensity shuttle running (Phillips et al., 2010) and sport-specific skills (Dougherty et al., 2006). Carbohydrate may exert these performance-enhancing effects by maintaining blood glucose concentration, enhancing carbohydrate oxidation, and/or through its effects on the central nervous system (Burke et al., 2011). Solid and liquid forms of carbohydrate appear to have similar benefits (Pfeiffer et al., 2010), thus athletes can decide which form works best for their individual preference/needs.

It is unclear why carbohydrate intake was so inadequate in these team-sport athletes, since they had access to 6% carbohydrate sport drink during practices, strength and conditioning workouts, and competitions. Instead, it may be due to a lack of knowledge/education about the importance of carbohydrate ingestion during exercise. In line with our findings, Jonnalagadda et al. (2001) reported that 97% of 31 freshman NCAA Division I football players believed fluids should be replaced before, during, and after athletic events but only 3% believed that fluids losses should be replaced with sports drinks (i.e., carbohydrate). Kavouras et al. (2012) conducted a study to determine the effect of an educational intervention program emphasizing increased fluid intake in youth athletes at a sports camp. At the end of the sports camp, they found improved hydration status in the intervention group, but no change in the control group that did not receive hydration education. It would be useful to conduct similar studies on the effectiveness of carbohydrate education in team-sport athletes.

Several previous studies have reported 24-hr energy, carbohydrate, and protein intake using food survey methods, such as food frequency questionnaires or food records. In a 2011 paper, Holway and Spriet summarized the 24-hr dietary intake of team-sport athletes across a broad age-range (youth, collegiate, and professional level) from reports published in the last 30 years. They found that mean energy intake was 3660 kcal for male and 2064 kcal for female athletes. Among youth-specific (14–19 yr) food survey studies with elite level, highly active team-sport athletes', 24-hr energy intake was 3952 kcal/d for males (Rico-Sanz et al., 1998) and 2013–2248 kcal/day for females (Beals, 2002; Gibson et al., 2011; Papadopoulou et al., 2002). Interestingly, these previously reported energy intakes are very comparable to that of the current study for both male (3522 kcal) and female (2132 kcal) athletes. It is also noteworthy that there were sex differences in energy intake relative to energy expenditure in the current study. Male athletes consumed enough energy to match expenditure ($p$ = .419), but for female athletes there was a trend for under-eating (-1012 kcal, $p$ = .108) in the 24 hr in which they were observed. This finding corroborates the notion that inadequate energy intake may be more prevalent in female than male athletes (American Dietetic Association et al., 2009; Sundgot-Borgen & Torstveit, 2004), including in team-sport athletes. Most of the under-eating by the female athletes occurred in tennis, which may be related to the fact that they were competing in matches on the day of observations. Others have also reported that although energy expenditure tends to be higher on match days than training days (Burke et al., 2006), athletes tend to eat less on match days (possibly due in part to game stress; Holway & Spriet, 2011).

The reported mean daily carbohydrate intake in previous food survey studies from the Holway and Spriet paper (2011) was 5.6 g/kg and 4.0 g/kg for male and female athletes, respectively. We also found a sex difference in daily carbohydrate intake relative to recommendations. In the current study, 24-hr carbohydrate intake in the male athletes was adequate (i.e., significantly greater than 5 g/kg). By contrast, 24-hr carbohydrate intake by most female athletes fell short of the recommended amount. The reported mean daily protein intake in previous food survey studies from the Holway and Spriet paper (2011) was 1.8 g/kg and 1.2 g/kg for male and female athletes, respectively. Overall, it is apparent that most team-sport athletes, including females, consume adequate protein (>1.2 g/kg) to meet daily recommendations. This is similar to previous food survey reports in elite youth female soccer players from Gibson et al. (2011) and female athletes from a variety of team sports from Heaney et al. (2010). Furthermore, male athletes in the current study consumed significantly more than the upper bound of the recommended range (1.7 g protein/kg), which is consistent with previous studies (de Sousa et al., 2008; Juzwiak et al., 2008).

## Limitations and Future Directions

Instead of using food frequency questionnaires or food records, we conducted dietary observations to more accurately (Conway, Ingwersen, & Moshfegh, 2004; McPherson et al., 2000; Mertz, 1992; Rumbold et al., 2011; Smith et al., 2007) determine what the athletes actually consumed before, during, and after practices and competitions. However, since only one day of dietary intake was observed it is possible that the results may not represent the athletes' usual energy, carbohydrate, or protein intake. In addition, the athletes' awareness that they were being observed may have affected their food/beverage choices. However, we took several measures (e.g., asking subjects to eat/drink as they normally would, providing no feedback, and minimizing intrusiveness) to limit the impact we had on the athletes' food choices. Moreover, despite the awareness that their dietary intake was being observed and documented, many athletes still consumed inadequate amounts of nutrients before, during, and/or after exercise. Nonetheless, as a future direction, it would be important to investigate how the athletes' intake around the active occasion varies from day-to-day or game-to-game by observing several days of athletes' sports nutrition habits or by supplementing with food records to confirm that observation data represent usual intake. More information regarding the subjects body weight stability should also be assessed in future studies.

This study tested a relatively small sample size and consisted of predominantly male athletes. A lack of significant differences found in some comparisons of intake vs. recommendations can likely be attributed to low statistical power. For example, this likely accounts for the lack of statistical difference found between energy intake and energy expenditure in the female athletes. Therefore, results have also been presented as a percent of athletes consuming adequate carbohydrate/protein to facilitate interpretation of practical significance.

## Summary and Practical Implications

The main finding from the dietitians' 24-hr dietary observations was that most 14–19 year old male and female highly-active, competitive skill and team-sport athletes consumed inadequate carbohydrate during exercise, relative to current sports nutrition recommendations. Another finding was that most female athletes failed to meet the minimum recommended intakes for 24-hr carbohydrate and postexercise carbohydrate and protein. By contrast, most male athletes consumed, and in the case of protein, over-consumed, adequate nutrition before and after exercise as well as in a 24-hr period. In conclusion, nutrition education for skill and team-sport athletes should be targeted toward improving female athletes overall nutrition and carbohydrate intake of both sexes during exercise to meet the 30–60 g/h recommendation to support sports performance.

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