ENERGY EXPENDITURE AND DIETARY INTAKE OF FEMALE COLLEGIATE TENNIS AND SOCCER PLAYERS DURING A COMPETITIVE SEASON

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Abstract:

This study examined energy expenditure, dietary behavior, and energy balance of female tennis and soccer student-athletes during a competitive season. A sample of 18 (M_{age}=19.86±1.35 years) Division I female collegiate student-athletes (5 tennis and 13 soccer players) were followed for four days, i.e., during one game/match, two practice sessions, and one recovery day. Physical activity was assessed with accelerometers and dietary behavior with daily food logs. Daily energy expenditure for the game/match, practice, and rest days was 2,848±304kcal, 2,622±248kcal, and 1,833±959kcal, respectively, with a statistically significant main effect ($F[2,16]=82.291$, $p<.001$, $\eta^2=.91$). Daily dietary intake ranged from 1,833±959 to 1849±371kcal, with no significant interaction between different days. There were no sport specific differences in energy expenditure or dietary behaviors. Athletes consumed 4.30±2.07 g/kg carbohydrates, 1.57±.98 g/kg protein, and 1.27±.80 g/kg fats daily. There was a significant main effect in dietary intake ($F[2,16]=7.311$, $p=.006$, $\eta^2=.48$), with a difference between game/match and recovery days ($t[17]=3.83$, $p=.001$, $d=1.19$). This study showed a negative energy balance among female student-athletes. The findings indicate that the lack of carbohydrate intake during game/match days contributed to this energy deficit.

Key words: *accelerometry, dietary recall, football*

Introduction

Female participation in intercollegiate sports has steadily increased after the enactment of the Title IX in 1972. It is reported that there are more than 200,000 female intercollegiate athletes, with an average of 8.83 teams per National Collegiate Athletic Association school (NCAA, 2016). Tennis and soccer are among the top female sports at the collegiate level, with 90%/80% of universities having female soccer and tennis teams, respectively (NCAA, 2016).

Adequate energy balance, i.e., the balance between energy intake and total energy expenditure (EE) (Hall, et al., 2012; Nordic Council of Ministers, 2012; Thomas, Erdman, & Burke, 2016) is essential for a high-level athletic performance (Thomas, et al., 2016). Resting EE (or basal metabolic rate), diet-induced thermogenesis, and EE caused by physical activity contribute to total EE (Hall, et al., 2012; Nordic Council of Ministers, 2012). The basic unit of EE is kilojoule (kJ), and one kJ equals to 0.24 kcal (or 1 kcal=4.184 kJ), a unit which is more commonly used in literature (Nordic Council of Ministers, 2012; Thomas, et al., 2016). Resting EE occurs when an individual is at a physical and mental rest in thermoneutral surroundings approximately 12 hours after a meal (Nordic Council of Ministers, 2012). Diet-induced thermogenesis can be defined as the increase in EE above resting EE divided by the energy content of the food ingested (Nordic Council of Ministers, 2012). Diet-induced thermogenesis provides a person approximately 5%, 20%, or 10% of the energy content of fat, protein, and carbohydrates, respectively (Nordic Council of Ministers, 2012; Thomas, et al., 2016).

Due to an increased demand of EE and the importance of maintaining lean tissue mass, immune and reproductive function, as well as optimal athletic performance among female athletes, national recommendations have been established to guide athletes in dietary behaviors (Thomas, et al., 2016). The recommendation of the American College of Sport Sciences indicates that athletes' basic intake of nutrients should include protein 6-10 g/kg/day, carbohydrates 1.2-2.0 g/kg/day, and fat less than 30-35% of the total kcals (less than 10% from saturated fat) per day (Burke, Hawley, Wong, & Jeukendrup, 2011; Thomas, et al., 2016). In addition, it has been suggested that daily carbohydrate intake during twice-a-day practice periods should be as much as 12 g/kg (Burke, et al., 2011).

Previous studies have shown match play EE of the female tennis players to be 7.4±1.3kcal per minute on average (Ranchordas, Rogerson, Ruddock, Killer, & Winter, 2013), whereas soccer players' game play EE has been found to be 7.2±1.2 (Mara, Thompson, & Pumpa, 2015). On the other hand, the game/match play EE values for male tennis and soccer players have been shown to be 10.8±1.8 (Ranchordas, et al., 2013) and 11.68±2.7kcal per minute (Garcia, Santo, Garcia, & Nunes, 2005), respectively. It has been shown that elite female tennis players expend on average 443±79 and 664±118kcal per 60min and 90min match, respectively (Hornery, Farrow, Mujika, & Young, 2007; Martin, et al., 2011; Mendez-Villanueva, Fernandez-Fernandez, Bishop, Fernandez-Garcia, & Terrados, 2007; Ranchordas, et al., 2013), whereas female soccer players expend estimated 966kcal during a 90min game (Mara, et al., 2015). Although a South Korean study (N=8; 19-24-year-old) showed EE of female college players to be daily 2,780±429kcal (Ndahimana, et al., 2017), the study did not report the expertise level of the players or the structure of their week (how many practices or matches they played). On the other hand, it has been shown that professional female soccer players' energy intake during preseason training (N=21; 3 hours of training daily) is on average 2,701±214kcal (Santos, Silveira, & Cesar, 2016). In addition, it has been reported that female soccer players' daily EE varies between EE of a recovery day 2,274±94kcal, training day 2,794±65kcal, and game day 2,925±144kcal (Mara, et al., 2015).

Research has shown female collegiate athletes' energy and macronutrient intake to be significantly lower than their energy needs (Shriver, Betts, & Wollenberg, 2013) and the recommended guidelines (Thomas, et al., 2016). Among female athletes, a long-term negative energy balance and inadequate nutrient intake have been associated with various health consequences, including menstrual dysfunction (Łagowska, Kapczuk, Friebe, & Bajerska, 2014; Márquez & Molinero, 2013), reproductive disorders (Loucks, 2004), low iron intake (Ahmadi, Enayatizadeh, Akbarzadeh, Asadi, & Tabatabaee, 2010), and loss of bone mineral density (Łagowska, et al., 2014; Nichols, Sanborn, & Essery, 2007). For instance, the study of Shiver et al. (2013), examining 54 female college athletes (the study did not specify the sport the participants were involved in), showed that only 9% of the participants met their daily energy needs and 75% of the participants failed to consume the minimum amount of carbohydrates required to adequately support training (Shiver, et al., 2013). There are, however, no publicly available studies to report female tennis players' dietary intake or energy balance. It is reported, however, that female athletes' energy intake is estimated to be about 70% of that of their male counterparts (Burke, Cox, Cummings, & Desbrow, 2001), and energy deficit is rather common among tennis players (Juzwiak, Amancio, Vitallem, Pinheiro, & Szejnfeld, 2008). It has been shown that female soccer players' daily energy intake (N=21) to be 2,306±405kcal, and that has resulted in the energy deficit largely due to a low carbohydrate intake (daily 5.5±0.9 g/kg) (Santos, et al., 2016). On the other hand, in this study the intake of protein (2.0±0.5 g/kg) and fat (26.3%±5.6 g/kg) were reported to be within recommendations (Santos, et al., 2016). Mullinix et al. reported average daily carbohydrates intake to be 4.7 g/kg/player among the players of the United States women's under-21 national soccer team (Mullinix, Jonnalagadda, Rosenbloom, Thompson, & Kicklighter, 2003), whereas Clark, Reed, Crouse, and Armstrong (2003) reported intakes for the American Division I college players of 5.2 g/kg/day before the season and when training twice a day and 4.3 g/kg/day about 10 days after the end of the competitive season.

The reviewed literature showed that there is a lack of scientific evidence to help female college athletes balancing their diet to maximize their athletic potential. It is especially important to understand energy balance of the Division I tennis and soccer collegiate athletes since they are exposed to the uniquely combined pressures of athletic performance and academic excellence that may put some additional pressure on student-athletes (Wycliffe & Simiyu, 2010). In addition, considering the health consequences, such as menstrual dysfunction (Łagowska, et al., 2014; Márquez & Molinero, 2013), reproductive disorders (Loucks, 2004), and loss of bone mineral density (Łagowska, et al., 2014; Nichols, et al., 2007), which a prolonged low energy balance among females may cause, comprehensive research efforts are warrant to examine daily EE and nutrition intake that factors to college athletes' low energy balance. Therefore, the first aim of the current study was to examine EE, dietary intake, and energy balance of female college tennis and soccer student-athletes during a competitive season. Second, this study aimed to examine the differences in EE, dietary intake, and energy balance between game/match, practice, and rest days as well as between tennis and soccer players.

Methods

Research design

The sample was followed for four days (96 hours) during student-athletes' competitive season. For both tennis and soccer, the 4-day period included one game/match day, one recovery day, and two training days (practices two times a day

– one gym and one field). Student-athletes' physical activity was measured objectively with a waist-worn accelerometer and dietary behavior with a daily food recall. Data collection strategy enabled the within- and between-group testing between different days and sports.

Participants

A sample consisted of 18 (M_{age}=19.86±1.35 years, age range 18-23) Division I female collegiate student-athletes (13 soccer and 5 tennis players) in the university located in the United States Mid-South area (Table 1). The Institutional Review Board accepted the study protocols, and participants' consents were obtained prior to the beginning of the study. Data were collected in fall 2014 during the athletes' competitive season. All participants were starters in their teams and they were healthy to train and play during the study.

Table 1. Participants' characteristics

	N	Age (SD) years	Ethnicity % b/w/a/h/o	Height (cm)	Weight (kg)	BMI	Years in sport	Received scholarship % f/p/n
Tennis	5	19.66 (.58)	48/38/3/3/7	171.13(1.59)	166.63(1.47)	19.75(1.27)	13.4	100/0/0
Soccer	13	19.85 (1.40)	56/30/6/4/2	166.63(4.87)	59.90(4.87)	21.55(1.70)	12.0	69.23/30.77/0
Both	18	19.86 (1.35)	52/34/4/4/6	167.83(4.83)	59.36(5.73)	20.83(1.74)	13.2	80/20/0

Note. f = full, p = partial, n = no scholarship. b = Black, w = White, a = Asian, h = Hispanic, o = other ethnicities.

Study protocol

Participants were instructed to wear the GT3X+ accelerometer (ActiGraph, LLC, Pensacola, FL) with the elastic belt fastened around the waist with the device positioned over the right hipbone for four consecutive days. Participants were instructed to wear the unit all day while awake. The only times they were able to remove the devices were sleeping or when showering or swimming. Participants completed a detailed log to track their wear and non-wear time. In addition, the participants were instructed to keep a food diary daily and document all food and beverage intake for four days using standard household measurements. The participants were provided with detailed tracking forms and a booklet of 2-dimensional food models to assist with the accurate portion size determination. Dietary intake assessment occurred concurrently with the physical activity assessment. To increase participant compliance, participants were contacted daily using text messaging.

Instrumentation

Anthropometric tests. The body composition variables of body height (m) and body weight (kg) were measured in each player. Weight was measured to the nearest 0.1 kg using an electronic weight scale, and height was measured to the nearest 0.1cm using a stadiometer (Seca 770 & 214, Seca Corp., Chino, CA, USA). Body mass index (BMI) was calculated in kg/m^2.

Habitual physical activity. Accelerometer data were collected following the best practices for physical data collection (Matthews, Hagströmer, Pober, & Bowles, 2012). Thirty Hz frequency responses with 1-second epochs were used. Participant EE during awake time was calculated using EE estimation of Freedson VM3 Combination ('11) (Sasaki, John, & Freedson, 2011). Non-wearing time was monitored manually using accelerometer data and log sheets. In case of missing or conflicting information, participants were contacted individually to clarify the disparities. Energy expended while sleeping was calculated using an algorithm utilizing body surface area, basal metabolic rate, and sleeping time. Body surface area (m^2) was calculated using the standard equation of .007184 height$^{.725}$ x weight$^{.425}$ (DuBois & DuBois, 1916). Basal metabolic rate (kcal x min^{-1}) was calculated as follows: 35 x body surface area (m^2) x 60. Finally, basal metabolic rate was multiplied with sleeping hours. Energy expended while not wearing a device was calculated using metabolic equivalents of task estimations presented in the Compendium of Physical Activities (Ainsworth, et al., 2011). Metabolic equivalent minutes were then transferred into kcals. Energy expended during sleep and non-wear tasks were then manually added to total EE estimation.

Habitual dietary intake. Dietary intake, including total energy and macronutrient intake, was assessed using detailed 4-day food intake records (Carlsen, et al., 2010). To ensure clarity and completeness of the food records, research staff together with the participant reviewed the returned records.

Statistical analysis

Physical activity data were processed with ActiLife 6 software and dietary intake with the Nutrition Data System for Research (Harnack, et al., 2008). All data were analyzed using SPSS version 22.0 (SPPS Inc., Chicago, IL, USA, 2017) with the statistical significance set up at $p<.05$ and Cohen's *d* effect size to .2=small, .5=moderate, and .8=large (Cohen, 1988). An average for total EE, dietary intake, energy balance, and macronutrient intake were determined for each participant. Three separate one-way within subjects analyses of variances were used to examine the differences in daily EE, dietary intake, and energy balance between game/match, practice, and recovery days. Significant main effects were further investigated using multiple pairwise *t*-test comparisons with Bonferroni correction (per Bonferroni equation the statistical significance was moved to $p<.016$). Independent *t*-test analyses were conducted to examine the differences between soccer and tennis players.

Results

Mean of EE, dietary intake, and energy balance are described for each participant in Table 2. All players' BMI was within normal weight range. Total daily EE for the 4-day period was 2,501±190 kcal/day, with daily EE of 2,557±113kcal among tennis and 2,485±208kcal among soccer players. EE for game/match, practice, and recovery days are presented in Figure 1 and they were 2,848±304kcal, 2,622±248kcal, and 1,833±959kcal, respectively. A one-way within subjects analyses of variance showed a significant main effect ($F[2,16]=82.291$, $p<.001$, $\eta^2=.91$), whereas *post-hoc t*-test comparisons with the Bonferroni correction identified significant differences between game/match and

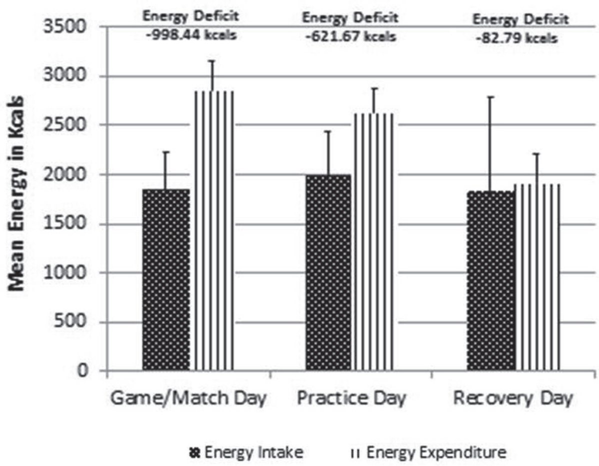

Figure 1. Energy expenditure, dietary intake, and energy balance during the four days of the competitive season.

Table 2. Energy expenditure and dietary intake

Participant	Sport	EE Mean kcal/day	DI Mean kcal/day	EB Mean kcal/day	Carbohydrates g/kg/day	Protein g/kg/day	Fats g/kg/day
1	Tennis	2578.59	1814.67	-763.91	3.28	1.49	1.54
2	Tennis	2565.80	2297.80	-268.00	5.10	1.80	.91
3	Tennis	2679.75	1924.60	-755.15	5.64	1.52	.82
4	Soccer	2242.18	1593.12	-649.06	2.38	1.74	1.32
5	Soccer	2356.71	1593.25	-763.46	3.96	1.11	1.05
6	Soccer	2439.77	2472.17	32.40	5.76	1.64	1.47
7	Soccer	2500.29	1541.53	-958.75	2.15	1.23	1.15
8	Soccer	2359.57	1331.93	-1027.64	1.43	.66	.38
9	Soccer	2236.92	2235.51	-1.42	5.27	.95	1.21
10	Soccer	2441.21	1853.01	-588.20	4.51	1.33	1.11
11	Soccer	2726.33	1735.18	-991.15	3.71	.71	.97
12	Soccer	2354.76	1431.01	-923.75	2.73	1.47	.80
13	Soccer	2210.63	2337.22	126.59	4.38	1.39	1.09
14	Soccer	2679.29	2724.77	45.48	10.98	5.29	4.24
15	Soccer	2714.74	2203.78	-510.97	4.69	1.65	1.52
16	Soccer	2754.92	1612.63	-1142.29	2.79	1.09	.73
17	Tennis	2784.95	1863.97	-920.98	3.32	1.61	1.10
18	Tennis	2405.63	2005.31	-400.32	4.28	1.57	1.14
Soccer		2,485.87(207.68) [2,210.63, 2,784.95]	1,894.93(427.51) [1,331.93, 2,724,77]	-590.94(456.18) [-1,142.29, 126.59]	4.21(2.31) [1.43, 10.98]	1.56(1.13) [.66, 5.29]	1.31(.89) [.38, 4.24]
Tennis		2,557.44(113.32) [2,405.63, 2,679.75]	2,010.60(206.80) [1,814.67, 2,297.80]	-546.85(251.49) [-763.91, -286.00]	4.57(1.02) [3.28, 5.64]	1.60(.14) [1.49, 1.80]	1.13(.33) [.82, 1.13]
Grand Mean		2,501.78(190.23) [2,210.63, 2,784.95]	1,920.63(386.98) [1,331.93, 2,724.77]	-581.14(413.10) [-1,142.29; 126.59]	4.30(2.07) [1.43, 10.98]	1.57(.98) [.66, 5.29]	1.27(.80) [.38, 4.24]

Note. EE = energy expenditure; DI = dietary intake; EB = energy balance.

practice (t[17]=2.912, p=.010, d=.66), game/match and recovery (t[17]=13.224, p<.001, d=2.26), and practice and recovery days (t[17]=7.606, p<.001, d=4.04). Independent samples t-tests showed no difference between EE of the tennis and soccer players (t-values ranging from .149 to 1.204).

Participants' dietary intake was 1,920±387 kcal/day, with daily intake of 2,011±207 kcal/day among tennis and 1,895±428 kcal/day soccer players. Dietary intakes were for game/match, training, and recovery days 1849±371 kcal/day, 2,000±435 kcal/day, and 1,833±959 kcal/day, respectively. The analysis showed no significant interaction between different days (F[2,16]=.547, p=.589, η^2=.06), or between tennis and soccer players (t-values ranging from .299 to 1.206).

Table 2 illustrates that only three players (all soccer players) had positive energy balance and the rest of the sample had energy deficit. On average, the daily energy balance was -581±413kcal; among tennis and soccer players the balance was -546±251 kcal/day and -590±456 kcal/day, respectively. In addition, the data showed that none of the players had a positive energy balance on the game/match or practice days, but five players (28%) had a positive energy balance during recovery day. The analysis showed a significant main effect in (F[2,16]=7.311, p=.006, η^2=.48), with *post-hoc t*-test comparisons with Bonferroni correction differences between game/match and recovery days (t[17]=3.83, p=.001, d=1.19). Independent samples t-tests showed no difference between EE of the tennis and soccer players (t-values ranging from .183 to .908).

Finally, the athletes consumed daily on average 4.30±2.07 g/kg carbohydrates, 1.57±.98 g/kg protein, and 1.27±.80 g/kg fats. Tennis players consumed 4.57±1.02 g/kg/day carbohydrates, 1.60±.14 g/kg/day protein, and 1.13±.33 g/kg/day fats, while the soccer players' daily consumption was 4.21±2.31 g/kg, 1.56±1.13 g/kg, and 1.31±.89 g/kg of carbohydrates, protein, and fats, respectively.

Discussion and conclusions

Considering the importance of energy balance to female athletes' performance and health (Clarke, Reed, Crouse, & Armstrong, 2003; Mara, et al., 2015; Maughan & Shirreffs, 2007; Ndahimana, et al., 2016; Santos, et al., 2016), the efforts to understand college student-athletes' EE and dietary intake are well warranted. The study showed that athletes' EE averaged 2,501 kcal/day, with no significant differences between tennis (2,557 kcal/day) and soccer (2,485 kcal/day) players. The EE values of this study were similar to those in the previous studies that have shown daily EE values to be 2,780kcal among female tennis players (Ndahimana, et al., 2017) and between 2,274kcal and 2,925kcal among soccer players (Mara, et al., 2015; Santos, et al., 2016). It is noteworthy that Ndahimana et al. (2017) study did not report the expertise level of the tennis players or how many practices or games the sample had during their study. The current study evidenced that athletes expended most energy during the game/match days and least energy during the recovery days. It was noticeable that both tennis and soccer players expended more energy during the game/match days compared to the twice-a-day training days. These findings, together with the findings of Mara et al. (2015), show that female tennis and soccer players' EE exceed the EE of normal population and, thus, highlights the importance of appropriate and sufficient dietary intake.

The findings of this study showed that tennis players' dietary intake was 2,011 kcal/day and soccer players' 1,895 kcal/day, with no differences between game/match, practice, or recovery days. Santos et al. (2016) have previously reported professional female soccer players' daily energy intake to be on average 2,306kcal, which is almost 500kcal more compared to the sample of this study. In addition, this study was one of the first studies to demonstrate female tennis players' daily dietary intake. Future studies are needed to examine whether a low calorie diet is prevalent among female student-athletes. Although there were differences between athletes' EE during game/match and recovery days, this study shows that athletes' dietary habits did not reflect the increased energy demand of the game/match days. This is highly important considering the negative outcomes that prolonged energy deficit have on athletic and academic performance (Thomas, et al., 2016).

The documented increase in EE and insufficient energy intake during the game/match day contributed to participants' low energy balance. This study documented all players to have a negative energy balance on both the game/match and practice days, whereas five players had a positive energy balance on the recovery day. This study showed no sport specific differences in total energy balance or macronutrient consumption. The players of this study consumed an average of 4.30 g carbohydrates, 1.57 g protein, and 1.27 g (<18%) fats daily. The findings of this study were similar to the findings of Santos et al. (2016), which had shown professional female soccer players to consume daily 5.5 g/kg carbohydrates, 2.0 g/kg protein, and 26.3% fat. Similar to Santos et al., (2016), this study showed that the carbohydrate deficit was the biggest contributor to the negative energy balance. Both tennis and soccer players consumed carbohydrates only an average of 4.30 g/kg a day, which is well below the recommendation of 12 g/kg (Burke, et al., 2011). On the other hand, the intake of protein and fat was reported to be within recommendations (Nordic Council of Ministers, 2012; Thomas, et al., 2016). This study extends the findings of the previous studies showing that the carbohydrates deficit during the game and practice days contributed to the found negative energy balance. If prolonged, this negative energy balance will lead to low energy availability, i.e., energy intake in relation to the energy cost of exercise (Loucks, 2004). Future studies are needed to determine if this energy deficit is continuous or if it was evident only during this 4-day study period. A window of four days is too short to determine athletes' long-term energy balance. Many studies, however, report that some athletes seem to be in negative energy balance, and such observations seem to apply more often to female athletes than to their male counterparts (Loucks, 2004; Maughan & Shirreffs, 2007; Shiver, et al., 2012). It has been argued that living in a restricted and negative energy balance is not unique to female athletes, but women in western societies are under pressure to maintain a low body fat content and "good" appearance (Loucks, 2004). A significant long-term energy deficit or low energy availability can limit athletes' cellular maintenance, thermoregulation, growth, and reproduction and, thus, be detrimental to their performance and health (Ahmadi, et al., 2010; Łagowska, et al., 2014; Márquez & Molinero, 2013; Nichols, et al., 2007).

There were few limitations in this study. First, the follow-up period of the study was only four days. An extended follow-up period would provide more trustworthy estimates of participants' energy balance. Second, food log method has been criticized for its inaccuracy and lack of validity (Yang, et al., 2010), mainly due to low response motivation and day-to-day variation in eating habits. Multiple recording periods across a year would have potentially increase assessment validity in energy consumption. It is noteworthy that the three-day food log has been shown to be more valid than the nine-day one, thus the longer follow-up period would not necessarily improve assessment validity (Yang, et al., 2010). Finally, athletes' physical activity was measured using waist-worn accelerometers. Although accelerometry can be regarded as the state-of-the-art measurement tool for free living physical activity, it is prone to a measurement error. Especially, EE estimation and wear time validation is problematic. This study utilized Freedson VM3 Combination ('11) for EE estimation (Sasaki, et al., 2011), and the wear time validation strategy has been reported under instrument section of this study. Future comparative studies are advised to utilize the same strategy.

This study shows that female tennis and soccer student-athletes' competitive season EE exceeds EE of normal population, and this energy deficit is especially prevalent during game/match days due to a lack of carbohydrate intake.

Practical implications

This study can be useful for tennis and soccer coaches and athletes alike. Based on the findings of this study, it can be recommended that athletes increase their carbohydrate intake specifically during game/match days. This will help student-athletes to perform better on the field and in classes.

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