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Effect of the intake of high or low glycemic index high carbohydrate-meals on athletes' sleep quality in pre-game nights

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Abstract: This study investigated the effect of the intake of high (HGI) or low glycemic index (LGI) high-carbohydrate meals on athletes' sleep. Nine basketball adult male athletes were assessed during a championship and received high-carbohydrate meals (dinner and evening snack) with HGI or LGI. Quantitative and qualitative sleep variables were assessed: sleep latency (LAT), sleep efficiency (EFIC), Wake After Sleep Onset (WASO), sleep time through actigraphy and sleep diary. Dietary intake, satiety, sleepiness, glycemic response, salivary cortisol and melatonin were also assessed. On both days most athletes had LAT and WASO higher than recommendation, and nocturnal sleep time below the recommendations. There was no difference between sleep and hormonal parameters according to GI dietary manipulations; however, correlations were observed between sleep and diet. Daily energy intake had negative correlation with efficiency and nocturnal total sleep time, and a positive correlation with WASO, regardless of the GI nocturnal meals. No differences were observed in salivary cortisol and melatonin according to GI. The results suggest that food intake throughout the day seems to exert more influence on sleep parameters of basketball players than GI manipulation of evening meals on the pre-night game, but further studies are necessary to better understand this complex relationship.

Key words: sleep, glycemic index, athletes, dietetics.

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INTRODUCTION

Diet plays an important role in athletes' performance (ACSM 2016). Among several dietary strategies used to optimize athletic performance, there is a consensus about the importance of carbohydrate intake before competitions (Burke et al. 2011, ACSM 2016). Studies show that diet can affect sleep (Afaghi et al. 2007, Lindseth et al. 2013, Nehme et al. 2014, Peuhkuri et al. 2012), and sleep can impact on athletic performance (Jullif et al. 2015). Athletes with sleep deprivation present impaired aerobic performance (Oliver et al. 2009) and reaction time (Taheri and Arabameri 2012), negative changes in mood (Scott et al. 2006), increased perceived exertion, and reduced time to exhaustion (Antunes et al. 2008).

Diet has been pointed out as a non-medical alternative to improve sleep. Studies conducted with non-athletes suggest that glycemic index (GI) manipulation can affect sleep, since high GI food intake reduced sleep onset latency (Afaghi et al. 2007). Besides latency, high GI was further associated with longer sleep duration (Diethelm et al. 2011) and with a better usual sleep quality (Yoneyama et al. 2014). However, the effect of manipulating athletes' diet on sleep has only been evaluated in one study (Killer et al. 2015). The ingestion of carbohydrate-rich drinks before, during and after a cycling training [totalizing 9.9(1.5) g/kg/day] was associated with lower sleep time than in control group (without carbohydrate increase) [7.4(1.6) g/kg/day], and the authors suggested that control group would need more sleep time to exercise recover (Killer et al. 2015).

Considering the lack of studies which investigate the variables related to sleep quality in athletes, we aimed to examine the effect of high (HGI) or low (LGI) glycemic index (GI) carbohydrate-rich meals on sleep parameters during a competition. The hypothesis was that HIG carbohydrate-rich meals would reduce sleep latency, resulting in better sleep quality on a pre-competitive night.

MATERIALS AND METHODS

PARTICIPANTS

Nine high-performance male, adult, basketball players, from a city in São Paulo state, Brazil, who participated in a state championship volunteered to participate in this study. Participants were included only if they agreed to follow the proposed diet, did not take medications related to sleep and did not have diseases directly related to carbohydrate metabolism. Before participation, athletes received verbal and written information about the study, and provided written informed consent. The study was approved by the Research Ethics Committee of the Universidade Federal de São Paulo, under appraisal #921.341/14.

STUDY DESIGN AND PROCEDURES

This is a cross-sectional study with a crossover design. Data was collected during three days (Figure 1) of a state championship.

One week before competition, participants answered a questionnaire about training characteristics and food history. Athletes went through anthropometric (body mass, height) and skinfold assessment, according to the recommendations of the International Standards for Anthropometric Assessment (ISAK 2001). Body mass index was estimated as well as body density (Jackson and Pollock 1978), which was converted to body fat percentage using Siri equation (1961).

Blood samples were collected in the morning (after 8 hours fasting) and glycaemia and lipid profile (cholesterol and triacylglycerol) were analyzed using Accu-chek® glycosimeter (Roche Ltd, Mannheim, Germany) and Accutrend® Plus glycosimeter (Roche Ltd, Mannheim, Germany), respectively.

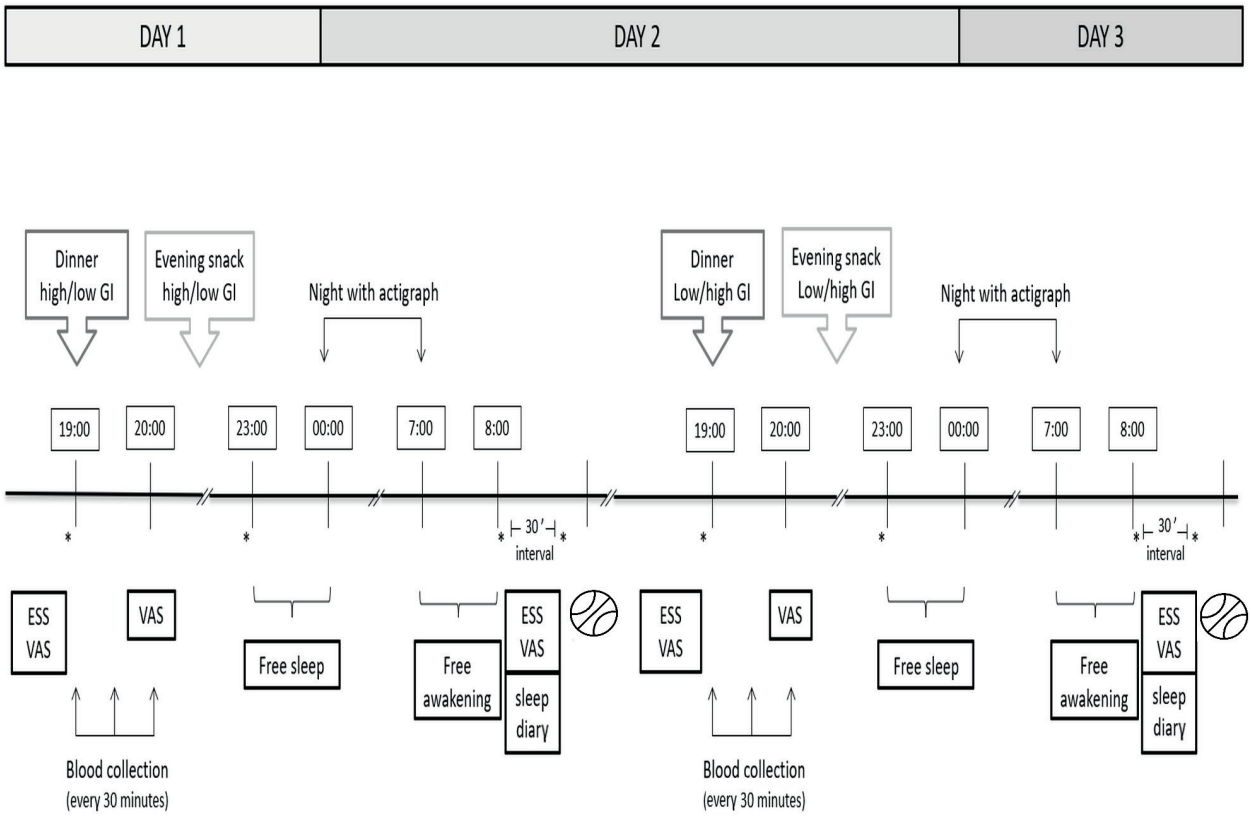

Figure 1 - Experimental study protocol.
*Saliva collection; basketball ball=basketball game. ESS=Epworth Sleepiness Scale; VAS=Visual Analogous Scale (for satiety and sleepiness). Blood collection was performed every 30 minutes after starting dinner intake.

To identify usual sleep quality, athletes answered the Pittsburgh Sleep Quality Index (PSQI) questionnaire (Bertolazi 2008), which classifies individuals with good (<5) or poor sleep quality (≥5) (Buysse et al. 1989). Aiming to evaluate chronotype, the Brazilian version of the Morningness-eveningness questionnaire (MEQ) was applied (Benedito-Silva et al. 1990). MEQ classification is: definite evening (16-30 points), moderate evening (31-41), intermediate (42-58), moderate morning (59-69) or definite morning (70-86) (Horne and Ostberg 1976).

All games were held in the morning (9h-12h), in two consecutive days. During the competition, athletes slept in a school, with mattresses disposed on classroom floor. The classroom had curtains on the windows, and athletes reported that the ambient light in the morning did not cause discomfort.

DIETARY INTERVENTION

The manipulated meals provided were defined based on athletes' habits and approved by participants. Except for the intervention meals (dinner and evening snack - ES), athletes' intake throughout the day was *ad libitum*. All food and drink consumed during the study were registered for dietary calculation (Nutrition Data System for Research® software). Participants were instructed not to consume coffee during data collection.

Athletes were randomly distributed in two groups, following the crossover design. Individuals consumed dinner and ES (Table I) on the nights of the first and second competition days.

TABLE I
Meals food composition (dinner and evening snack) with high and low GI.

GI	Dinner	*GI	Evening snack	*GI
High	White rice, cow meat (grilled), potato (without skin, baked), Gatorade® (tangerine flavor), jelly beans	74.9	Orange juice (unsweetened, reconstituted concentrate), cornflakes, cookie (honey and cocoa flavor), sandwich (white bread with butter and skim milk cheese)	71.8
Low	White rice, carioca beans, cow meat (grilled), apple juice (whole, unsweetened), cereal (rich in fiber), yogurt (whole milk, artificial strawberry flavored)	49.5	Chocolate milk, apple, cereal bar (hazelnut flavor), sandwich (white bread with butter and skim milk cheese)	47.9

*GI calculated using Wolever and Jenkins (1986) protocol.

GI meal values were estimated using Wolever and Jenkins (1986) method, and GI was classified as: low (≤55), medium (56-69) or high (≥70) GI (Atkinson et al. 2008). High and low-GI dinners and ES were isocaloric (p=0.22), and the dietary composition of meals are described in Table II.

On evaluation days, athletes were fasted for 3 hours. Blood collection for glycemic response analysis was conducted before dinner, 30 minutes and 60 minutes after the start of dinner. Participants agreed to eat dinner in a maximum 15 minutes interval (Afaghi et al. 2007). After dinner, athletes received a kit containing the ES, which also met the GI (high/low) consumed at dinner of the same day.

Before and immediately after dinner, participants answered to a visual analogous scale (VAS) (10cm) (Hindmarch 1980) to evaluate satiety, which contained the words "hungry" and "extremely satisfied" at the extremities (Afaghi et al. 2007).

SLEEP EVALUATION

Athletes were free to sleep and wake up whenever they wanted. The sleep pattern was assessed using an Ambulatory Monitorning Inc® actigraph (New York, USA), and data was read by Action-W® software (2.6 version, Ambulatory Monitorning, USA). The actigraph was used on non-dominant arm, and the parameters considered were: nocturnal total sleep time (NTST), daytime total sleep time (DTST), sleep efficiency (EFIC) (time of sleep divided by total time in bed), sleep latency (LAT) (time after lying down until sleep) and Wake After Sleep Onset (WASO).

Participants informed their bedtime and awakening time, if they woke up at night and how many times, and their subjective sleep quality (SSQ) (10cm scale) in a sleep diary. A VAS was used to assess sleepiness, which was indicated on a 10cm line with the words "not sleepy" or "sleepy" at the extremities (Afaghi et al. 2007). The Epworth Sleepiness Scale (ESS) (Bertolazi et al. 2009) was used to assess the daytime sleepiness. Results above 9 were considered as excessive daytime sleepiness. Individuals answered to VAS and ESS before dinner and in morning after meals manipulations.

HORMONAL ANALYSIS

Melatonin secretion was analyzed by salivary dosage (ELISA kit-IBL® International GMBH, Germany). Saliva collection was performed before dinner, before bedtime (≥60 minutes after ES) and right after awakening (still in bed), in the subsequent morning. Athletes received plastic tubes (salivettes®, Sarstedt, Numbrecht, Germany) with specific cotton for saliva collection and were instructed according to kit recommendations. Saliva samples were stored in a freezer at -5°C for three days, transported under refrigeration, and afterwards stored in a freezer at -20°C.

Cortisol levels were also evaluated through salivary cortisol dosage. The collection followed the same procedures described above, but with an additional collection point, 30 minutes after the

TABLE II
Meals food composition (dinner and evening snack) with high and low GI.

		Energy (kcal)	Carbohydrate (g)	Carbohydrate (%meal)	Protein (g)	Protein (%meal)	Fat (g)	Fat (%meal)
HGI	Dinner	833	130.8	62.8	36.2	17.4	18.4	19.9
	ES	1058	169.5	64.1	27.9	10.5	29.9	25.4
LGI	Dinner	924	129.9	56.2	47.5	20.6	23.8	23.2
	ES	1083	160.3	59.2	33.1	12.2	34.4	28.6

ES=evening snack; %meal=percentage of the meal (dinner or evening snack).

first collection in the morning, at fast. Analysis was performed using a commercial Cortisol kit (Salimetrics®, LLC, State College, PA, USA).

Information of temperature and air relative humidity was collected online (www.climatempo.com.br). Athletes' perceived exertion was evaluated through the Borg (1982) scale (0-10 scale).

STATISTICAL ANALYSIS

Data were analyzed by Graph Pad Prism software (5.01 version) and presented as median, minimum and maximum values and standard deviation. D'Agostino and Pearson test was applied to evaluate the normality of data distribution, while Levene's was used to homogeneity test. Considering the results and the small sample size, non-parametric statistical tests were adopted. The results of sleepiness, satiety, cortisol and melatonin were compared according to GI by Friedman test, followed by Dunn's Posthoc for multiple comparisons. To investigate the difference between sleep parameters, daytime sleepiness and food consumption according to the GI, Wilcoxon's test was applied. The glycemic response after dinner GI manipulation was evaluated using the area under the curve (AUC) of the two situations (HGI/LGI), which were compared using Wilcoxon's test. To evaluate the association between sleep parameters and the other factors and between food consumption and other parameters, Spearman's correlation coefficient was calculated. Statistical significance was set at $p<0.05$.

RESULTS

Participants were 18.0±0.7 years old, and presented mean values of 90.0±10.9 kg of body mass, 1.95±0.1 m of height, 23.9±1.5 kg/m^2 of Body Mass Index, and 10.6±3.2% of body fat percentage. Athletes had 7.0±4.5 years of basketball practice and trained 17.5±5.0 hours per week. The general daily exercise activities and duration reported by the athletes were two hours of general basketball training, half an hour of shooting baskets training and one hour of resistance (weight) training.

Fasted glycaemia, cholesterol and triacylglycerol were 96.0±6.3 mg/dL, 151.0±6.6 mg/dL and 80.0±11.8 mg/dL, respectively. Mean PSQI score was of 5.5 (3.2). Five (56%) had a PSQI score >5, indicating poor sleep quality. Six (67%) athletes were classified as chronotype "intermediate", two (22%) as "moderate morning" and one (11%) as "definite evening".

Perceived exertion (Borg 1982) was 4.5 (1.5) (3-7) before HGI and 5.0 (1.8) (3-8) before LGI, with no significant difference. Ambient temperature (25ºC and 24ºC), relative air humidity (100% and 97%) were similar on both days.

RESPONSE TO DIETARY INTERVENTION

Table III shows energy and macronutrients intakes on intervention days. Only carbohydrate intake (g/kg/d) was significantly different according to GI ($p=0.04$). After an individual analysis, it was noted that six athletes consumed more rice at lunch in

HGI day, resulting in higher daily carbohydrate intake.

There was a significant difference between the AUCs after HGI [237.0 (18.4)] and LGI [217.8 (19.8)] (p=0.006), indicating that the HGI glycemic response was higher than LGI, as expected (not shown). Glycemic response were 98.00 (9.3) and 99.0 (5.6) md/dL before dinner, 132.0 (15.9) and 120.0 (18.6) md/dL 30 minutes after the start of dinner, and 110.0 (18.7) and 100.0 (9.5) md/dL 60 minutes after the start of dinner, in HGI and LGI, respectively.

There was no difference in satiety according to GI [HGI: before dinner (BD) 2.4 (2.4); after dinner (AD) 5.8 (1.7); before breakfast (BB) 5.2 (2.1); LGI: BD 1.1 (2.0); AD 6.1 (1.9); BB 4.2 (2.2)] (no shown).

No significant differences were observed in sleepiness (VAS) in relation to GI. On HGI night, athletes' sleepiness scores were of 4.7 (2.9) BD; 4.9 (2.6) AD; and 4.5 (2.4) BB, whereas in LGI the sleepiness results were 4.0 (1.8) BD; 4.0 (1.4) AD; and 5.4 (2.4) BB (no shown). There was a negative correlation between LGI carbohydrate intake and sleepiness AD (r=0.70; p=0.04). A positive correlation was also observed after LGI, between AD sleepiness and subjective sleep quality (SSQ) (r=0.75, p=0.02), and a negative correlation between SSQ and sleepiness BD (r=-0.73, p=0.02). Concerning daytime sleepiness (ESS), it was observed that, regardless of the moment and GI, athletes presented excessive daytime sleepiness (>9) (Figure 2), with no statistical difference according to GI.

HGI daytime sleepiness had a positive correlation with the daily percentage of carbohydrate intake in relation to total energy value (CHO %EI) (r=0.77, p=0.02; r=0.90, p=0.001), and negative with daily protein intake (g/kg) (r=-0.77, p=0.02; r=-0.85, p=0.004), both at night and in the subsequent morning, respectively.

Table IV presents the results of sleep parameters evaluated by actigraphy. There was no statistical difference in sleep parameters according to GI. In HGI, 38% of the athletes had lower latency than recommended (30 minutes), whereas in LGI only 25% of them were below the recommendation. Regarding efficiency, in both nights 75% of the subjects were above the recommendation (85%), indicating satisfactory sleep efficiency. As for WASO, after HGI only one athlete was below the recommended limit (<30 minutes), while after LGI four athletes presented WASO values for adequate sleep.

Most athletes napped (daytime sleep) during both days. In the afternoon following HGI, seven athletes slept after lunch, and after LGI, eight athletes napped in the afternoon. No significant differences were found in daytime sleep according to GI.

No significant difference in subjective sleep quality was found between HGI [5.2 (1.4)] and LGI [4.0 (2.1)] nights. Figure 3 shows the nocturnal sleep parameters, compared to literature recommendations.

There were significant correlations between energy intake and sleep efficiency (HGI: r=-0.77; p=0.01; LGI: r=-0.84; p=0.03) and WASO (HGI: r=0.77; p=0.03; LGI: r=0.74; p=0.03).

Most athletes woke up at least one time in both nights (89% after HGI and 67% after LGI), but there was no significant difference in number of awakenings. Athletes indicated the bad quality of the mattresses and external noises at night (other teams) as the main reasons for awakenings.

In relation to salivary cortisol, no significant differences were observed according to GI, only between moments (Table V). The results showed an expected circadian rhythm, with lower levels at night and peak of greater levels at awakening. BD cortisol level on HGI was negatively correlated with sleep efficiency (r=-0.85, p=0.01) and positively with WASO (r=0.85, p=0.01). Correlations between these variables were also observed after awakening (AA) (sleep efficiency: r=-0.71, p=0.05;

TABLE III
Daily dietary information according to the GI consumed at evening meals (n=9).

	HGI	Min-max	LGI	Min-max
Energy (kcal/kg)	42 (5)	34-48	41 (4)	35-47
Fat (g/kg)	1.2 (0.2)	0.8-1.4	1.2 (0.2)	1.0-1.5
Protein (g/kg)	1.8 (0.49)	1.4-2.8	2.1 (0.4)	1.4-2.9
Carbohydrate (g/kg)	*5.8 (0.7)	4.9-6.8	5.4 (0.7)	4.7-6.8
Carbohydrate (% VET)	57.0 (3.5)	52.1-62.8	55.0 (3.7)	47.0-58.0

Values expressed as median (standard deviation). *Carbohydrate intake significantly higher on the day of HGI in relation to LGI (p=0.04).

TABLE IV
Sleep parameters according to dietary GI (n=8).

	HGI	Min-max	LGI	Min-max
Nocturnal total sleep time (minutes)	386.0 (74.9)	207-436	359.5 (56.7)	276-438
Daytime total sleep time (minutes)	98.0 (45.9)	37-176	101.0 (29.4)	94-166
Total sleep time (nocturnal + daytime) (minutes)	504.5 (86.3)	299-538	433.5 (86.9)	338-604
Nocturnal sleep latency (minutes)	33.5 (22.0)	4-71	46.0 (46.8)	3-150
Daytime sleep latency (minutes)	10.0 (14.7)	1-38	13.0 (12.9)	3-34
Nocturnal sleep efficiency (%)	89.9 (9.9)	66-98	91.1 (6.1)	79-96
Daytime sleep efficiency (%)	90.2 (9.8)	73.2-100	94.9 (8.1)	78.9-99.0
WASO of nocturnal sleep (minutes)	43.0 (31.5)	10-108	34.0 (27.3)	17-94
WASO of daytime sleep (minutes)	10.0 (20.4)	0-56	9.0 (10.4)	1-27

Values expressed in median (standard deviation), minimum-maximum. WASO=Wake After Sleep Onset. At the moment of reading the data, the record of one of the nine evaluated athletes was not stored in the actigraph, therefore it could not be analyzed (n=8).

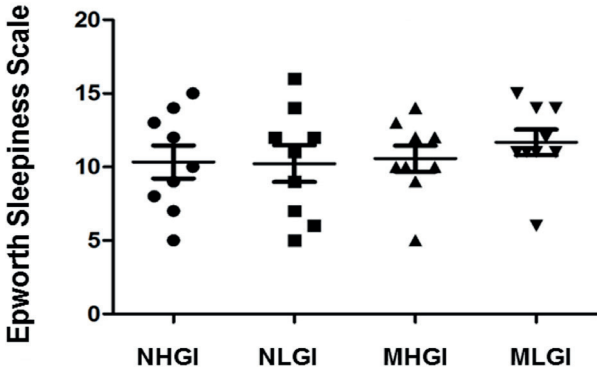

Figure 2 - Daytime sleepiness according to the moments (N=night and M=morning) and GI of the meals (HGI=high glycemic index and LGI=low glycemic index) (n=9).

WASO: r=0.71, p=0.05), after HGI. There was a negative correlation between BB cortisol with SSQ (r=-0.78; p=0.01), after LGI.

There was no difference in melatonin according to GI, only between collection moments in HGI. Significant differences were found between BD and AA (p<0.001), and before sleep (BS) and AA (p<0.01) (Table V).

In HGI, BS melatonin was positively correlated with sleep latency (r=0.74, p=0.04), and in LGI, AA melatonin was negatively correlated with nocturnal total sleep time (r=-0.76, p=0.03).

DISCUSSION

This is the first study to describe the effect of dietary manipulations on athletes' sleep during a competition. The results indicate that the majority of athletes presented poor sleep quality both usually (PSQI assessment) and during competition (actigraphy); the GI manipulation (dinner and ES) did not cause significant differences in sleep parameters; however, energy and nutrient intake

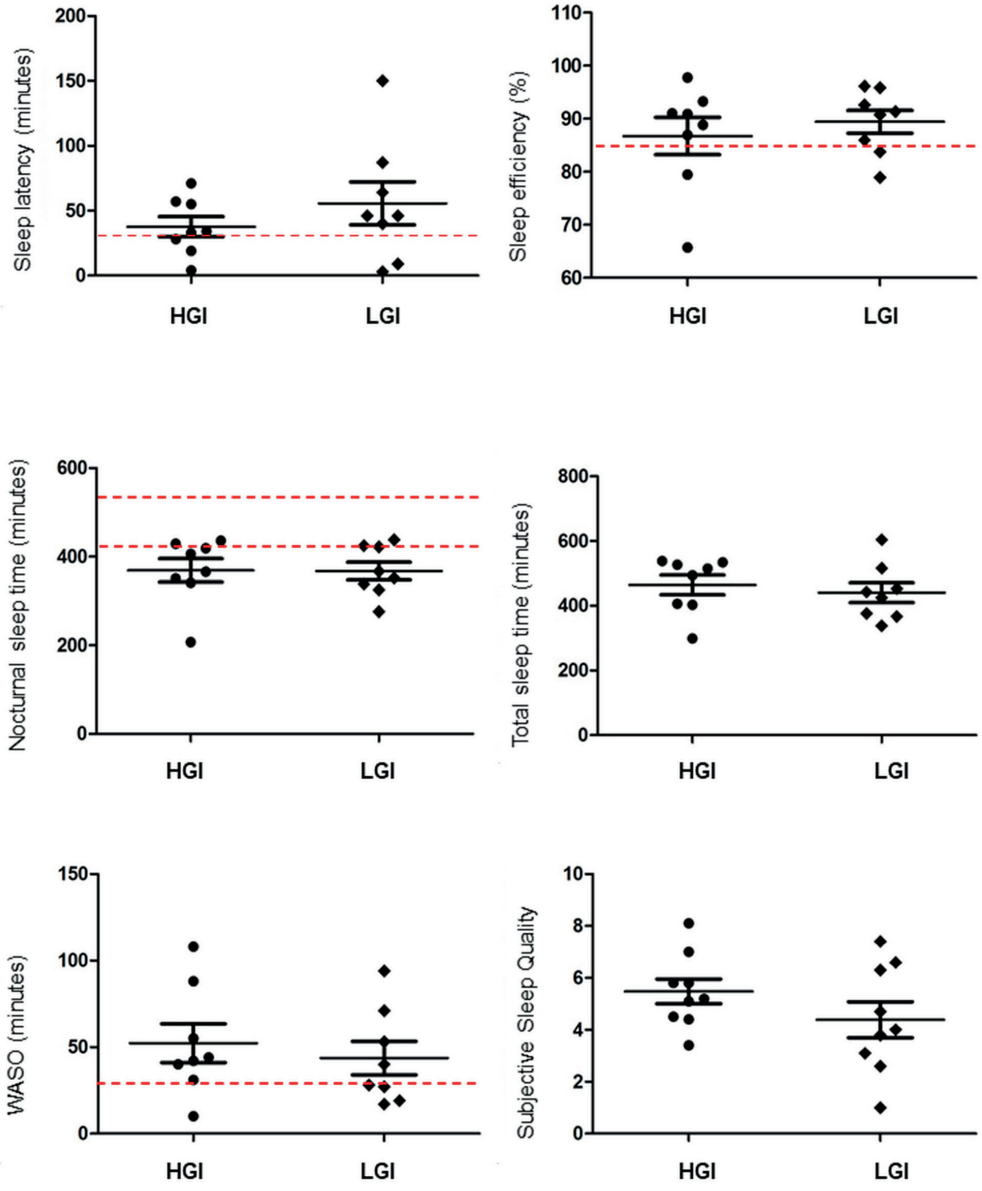

Figure 3 - Effect of different meals (HGI or LGI) on sleep (n=8). WASO=Wake After Sleep Onset. Dotted line indicates recommended values for normal adult sleep (Pinto and Silva 2008).

throughout the whole day seemed to influence sleep. The present study also contributes with information on sleep patterns and cortisol and melatonin responses.

Athletes' intake during intervention, was in accordance to the range of values suggested for collective sports athletes (Holway and Spriet 2011) and the evening meals proposed in this study were carbohydrate-rich (>55% of the meal), as recommended pre-competition (Burke et al. 2011). Although the crossover design in both intervention days, athletes had higher CHO mean intake in HGI. Nevertheless, the difference (p=0.04) of daily CHO intake between HGI and LCI, CHO intake was not correlated with sleep parameters.

Our results are different from other studies with non-athletes, in which carbohydrate-rich meals (Lindseth et al. 2013, Rodrigues 2015),

TABLE V
Median values of salivary cortisol and melatonin according to the time of collection and GI meals consumed.

Time of collection	Salivary cortisol (nmol/L)		Salivary melatonin (pg/mL)	
	HGI	LGI	HGI	LGI
Before dinner (BD)	1.7 (1.7)*	2.7 (2.0)	0.2 (0.1)##	0.1 (0.3)
Before sleep (BS)	0.5 (0.5)**	0.4 (0.6)#&	0.2 (0.2)***	0.3 (0.3)
After awakening (AA)	6.2 (4.1)**	6.4 (5.4)#	2.4 (2.3)##***	1.3 (1.5)
Before breakfast (BB)	13.0 (4.2)*	8.0 (4.2)&		

Values expressed in median (standard deviation).
Significant differences according to HGI and LGI in *p<0.05; **p<0.001; #p<0.01; &p<0.01; ##p<0.001; ***p<0.01.

especially HGI (Afaghi et al. 2007) were shown to reduce sleep latency. Our hypothesis that HGI's carbohydrate-rich meals could reduce sleep latency was based on the fact that after a HGI carbohydrate meal intake, there is an increase in the proportion of tryptophan:BCAA through a higher BCAA muscle uptake, due to an increase in insulin secretion in response to the meal (Wurtman et al. 2003). The tryptophan that crosses the blood-brain barrier is converted into serotonin and later into melatonin, so HGI carbohydrate-rich diets may increase melatonin secretion (Wurtman et al. 2003, Afaghi et al. 2007). Although no difference was observed between sleep latency according to the GI, after HGI more athletes presented latency within the recommended values for adults. Even among those athletes with sleep latency above recommended values, the higher values presented after HGI were even lower than after LGI. No association was found between WASO and HGI meals consumption in the literature.

Unhealthy values of athletes' sleep latency and efficiency before and during a competition have also been described in other studies (Shearer et al. 2015, Lastella et al. 2015). These results reinforce the need for greater attention and effort by the technical staff to improve athletes' sleep quality in competitions, especially considering that low sleep quality could impair performance (Oliver et al. 2009).

Actigraphy results showed higher values of sleep latency and efficiency and lower nocturnal total sleep time in comparison to values observed in elite athletes (Leeder et al. 2012). Although the need for sleep duration is individual, when comparing nocturnal total sleep time with the recommended for the age range (420-540 minutes or 7-9 hours) (Hirshkowitz et al. 2015), only 38% of the athletes slept more than the minimum suggested, on both nights. The nocturnal total sleep time of our study (on both nights) was also lower than observed in other basketball athletes in competition (Mah et al. 2011).

Although sleep plays an important role in exercise recovery (Dattilo et al. 2011), the necessary sleep time for athletes is not defined in the literature. Studies have shown that athletes' sleep duration can vary according to the exercise characteristics (intensity and duration), training sessions schedule and frequency of competitions (Leeder et al. 2012, Lastella et al. 2014). Differences between sports are also highlighted, indicating that in collective sports athletes usually sleep more than those involved in individual disciplines (Leeder et al. 2012, Lastella et al. 2014). Further studies on athletes' sleep are important to elucidate individual needs in this population.

A negative correlation between energy intake and sleep parameters (sleep efficiency and WASO) was found, independent of the GI. Differing from our results, Driver et al. (1999) observed

that the variation of daily energy consumed did not influence sleep of healthy adults. Although the influence of sleep on energy consumption is reported in the literature (i.e, sleep deprivation causing a consequent energy intake improvement) (Patterson et al. 2014), the consequences of daily energy intake on subsequent sleep are less known, so more investigations are necessary. It is suggested that daily energy intake and its effects on sleep quality are more investigated, especially among athletes, who generally have a high energetic intake compared to sedentary individuals, and may even increase their energy intake pre or during a competitive period.

Athletes in this study presented excessive daytime sleepiness on both days. This was expected as Juliff et al. (2014) pointed out that collective sports athletes have greater daytime sleepiness (48%) than individual sports athletes (27%). We believe that competition conditions (mattress, noise) may have impaired nocturnal sleep, and this has consequently increased subsequent daytime sleepiness. Considering that athletes had more free time to sleep after lunch than usual, napping may also have increased daytime sleepiness and interfered with subsequent nocturnal sleep, creating a vicious circle.

The association between dietary intake and daytime sleepiness corroborates with the literature, which suggests that a higher carbohydrate intake might increase sleepiness and protein ingestion might reduce it (Spring et al. 1983, Nehme et al. 2014). A greater sleepiness would induce sleep onset, which is desired before bedtime. However, an excessive daytime sleepiness could impair athlete's performance in daily sports activities, thus being undesirable. Distributing macronutrient consumption throughout the day may be an important strategy to control these effects.

Regarding salivary cortisol, the significant difference between collection times was already expected, since cortisol presents a circadian rhythm, with lower secretion at the beginning of the night and peak near to the moment of awakening (Saraiva et al. 2005). Other studies also did not observe difference in cortisol levels according to GI consumed, both in children (Micha et al. 2011) as in young adults (Micha and Nelson 2011) who consumed LGI and HGI meals.

Participants had salivary cortisol AA similar to other basketball athletes [8.5 (2.1) nmol/L] (Januário et al. 2012) and slightly below soccer athletes [12.4 (2.4) nmol/L] (Minetto et al. 2008). Although several studies investigated cortisol secretion in athletes, the methods and moments of evaluation differ or are not clearly described, so there is need to standardize it for comparison and discussion with reference parameters (Dos Santos et al. 2014).

Cortisol levels in HGI indicated that the higher its BS levels, the worse was sleep quality (lower sleep efficiency and higher WASO), as well as the greater subsequent levels of AA cortisol. Sleep impairment due to cortisol increase was also reported in other studies in healthy and with insomnia adults (Rodenbeck et al. 2002) and in one review (Bush and Hudson 2010), which highlighted that increased levels were associated with awakenings during the night. On the other hand, triathlon athletes' performance was positively correlated with salivary cortisol concentration in the early morning of a competition day (Balthazar et al. 2012). Therefore the relationship between cortisol levels and performance and sleep are not completely understood yet.

Values of salivary melatonin at the three collected moments were below values found in literature (5-20 pg/mL) (Arendt 2011). The highest values (AA) were still below the 10 pg/mL suggested for this moment (Arendt 2011), but this probably occurred by influence of the ambient luminosity. Even at night, saliva collection occurred while athletes were in the school hall, where the ambient lights were on. This is one of

the study's limitations, but this factor could not be controlled by the researchers. As known, melatonin has a circadian pattern directly influenced by the presence of light (Arendt 2011), and it has already been reported that a light intensity of incandescent lamps is enough to suppress melatonin secretion at night (Lewy et al. 1980), which was the condition at the collection moment and could have interfered in our results.

The positive correlation between pre-sleeping melatonin secretion and sleep latency after HGI contradicts the findings in the literature, which indicates melatonin as a regulator of the sleep process (Ferracioli-Oda et al. 2013, Gandhi et al. 2015). In the present study, a negative correlation between nocturnal total sleep time and AA melatonin secretion was observed after LGI. According to Bumb et al. (2014), sleep restriction could increase serum melatonin levels up to 75% in one night of sleep deprivation.

Regarding the correlations between melatonin and food intake, the results also do not corroborate with the literature. The expected increase in the melatonin concentration after HGI intake (Wurtman et al. 2003) was not observed. Considering that sleep is complex and may be related to several aspects (Carskadon and Dement 2011), it is suggested that other factors beyond food intake may have influenced the evaluated parameters. The short time interval between the meal and start of sleep could be a factor that interfered in these results, and perhaps with a longer interval, these expected effects could have been observed.

One of the limitations of the study is the small sample size, which can have influenced the statistical analysis. Furthermore, some collection conditions could not be controlled (e.g. ambient light and noise), which could have influenced the results. However, although researches with a controlled environment can minimize many of these conditions, they have the disadvantage of not representing the situation experienced in practice, being difficult to replicate the dynamics and behaviors that individuals will experience in the field (Gray 2014), therefore the collection in real competition situation has ecological validity and is a positive aspect of this study.

The fact that manipulated meals were proposed according to athletes' habits is another positive aspect. In other studies with meal GI manipulation, the provided food was not their usual meal [i.e. HGI or LGI rice and tomato puree with vegetables (Afaghi et al. 2007); instant mashed potato, boiled eggs and ketchup (HGI) or boiled red lentils (LGI) (Little et al. 2009); instant mashed potatoes (HGI) or müsli (LGI) (Febbraio et al. 2000)]. The interventions were proposed aiming to interfere as little as possible in athletes' activities and behaviors during the competition.

We suggest that further studies should compare sleep during a training period and in competition, and investigate the influence of GI meals of the whole day on sleep, not only the last (dinner and ES) ones.

CONCLUSION

No significant differences were observed in sleep parameters according to GI meals (dinner and ES) consumed at the night before a competitive basketball game.

Food intake throughout the whole day before competition should be planned, aiming not only to improve athletic performance, but sleep as well. It was observed that the higher the daily energy intake, the worse the sleep quality (lower efficiency and higher WASO), regardless of evening meals' GI. Daily energy consumption and its effects on sleep parameters have to be further investigated, especially among athletes, who generally have a high energy intake.

Based on the contribution of this study, it is expected that new studies in the area could be stimulated and that sports professionals become

more aware of sleep issues and possible strategies to optimize athletes' sleep.

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AUTHOR CONTRIBUTIONS

Authors ND, CJ, IZ, and RP are responsible for the conception and design of the study. ND collected all the data. ND, CJ, DE and MG analyzed data and interpreted the results. All authors contributed to the writing of the article, revised it critically and approved the final version.

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