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The Association Between Pregame Snacks and Exercise Intensity, Stress, and Fatigue in Children

Jennifer M. Sacheck, Helen M. Rasmussen, Meghan M. Hall, Tamar Kafka, Jeffrey B. Blumberg, and Christina D. Economos
Tufts University

To investigate the association between pregame snacks varying in macronutrient content and exercise intensity, physiological stress, and fatigue in young soccer players. One hour before a 50-min soccer game, children (n = 79; 9.1 ± 0.8 y) were randomly assigned to consume a raisin-, peanut-butter-, or cereal-based snack. Body mass index, blood glucose, and salivary measures of stress (cortisol and immunoglobulin A-IgA) were measured pre- and post-game. Exercise intensity was measured by accelerometry. Self-administered questionnaires were used to assess diet quality and fatigue. Analysis of covariance was used to examine the relationship between pregame snacks and biochemical outcomes. Postgame glucose and cortisol increased [12.9 ± 21.3 mg/dL ($p < .001$) and 0.04 ± 0.10 µg/dL ($p < .05$), respectively] and IgA decreased (–2.3 ± 9.6 µg/mL; $p < .001$) from pregame values. The pregame snack was not associated with exercise intensity or post-game outcome; however, children consuming the cereal-based (high-sugar and high-glycemic index (GI)) snack exercised more intensely than the 2 lower-GI snack groups ($p < .05$). Children who consumed the high-sugar, high-GI snack also reported more symptoms of fatigue ($p < .05$). A high-sugar, high-GI pregame snack was associated with exercise intensity and fatigue but not changes in blood sugar or stress biomarkers following a soccer game in children.

***Keywords*:** cortisol, salivary IgA, accelerometry, blood glucose, glycemic index

Background

Snacking can be critical for children who are involved in sports since they need adequate energy to support both normal growth and athletic activities, but nearly 40% of total calories consumed by children and adolescents are empty calories (i.e., provide energy but lack other nutritional value) (45). There are currently very few studies that examine how the composition of different snacks impacts children exercising in different sporting environments, with most studies at this time examining the effects of sports drinks on athletic performance (8,18,33,41–43).

Consuming carbohydrates before exercise has been shown to improve performance by ensuring adequate liver and muscle glycogen and maximizing the availability of glucose, the primary fuel used during exercise. Recently, much work has been done on the effects of the glycemic index (GI) of preexercise meals on exercise performance, immune response, and blood glucose in adults (10,23,30,48–50,54,55). Foods with a lower GI create a smaller increase in blood glucose and insulin when compared with higher-GI foods (17,25,50). Consequently, many studies have shown an increase in performance among subjects who ate a low-GI meal before exercise, compared with those who ate a high-GI meal (17,48,50,54,55). A recent study also concluded that the rating of perceived exertion was lower in adult athletes who had eaten lower-GI meals before exercise compared with high-GI meals (31). However, several studies have shown that the GI of a pre-exercise meal does not affect performance in high-intensity intermittent exercise (e.g., soccer) (23,31).

The macronutrient composition and nutrient density of snacks may also be important for children who play sports due to the increased physiological stress and fatigue which can impact inflammation and immune function (3,13,27,29). Research shows that consuming carbohydrates (6,39), and more specifically a low-GI carbohydrate meal (10), before exercise can attenuate the exercise-induced increase in cortisol and immune response, possibly due to the improved maintenance of glucose. However, some studies showed no difference (28,30,56). Furthermore, diets low in nutrient density may compromise immune responsiveness and promote excessive oxidative stress during these situations. Exercise

Sacheck, Hall, Kafka, and Economos are with the Friedman School, and Rasmussen and Blumberg the Jean Mayer USDA Human Nutrition Research Center on Aging, Tufts University, Boston, MA. Address author correspondence to Jennifer M. Sacheck at jennifer.sacheck@tufts.edu.

typically produces stress on the body that has beneficial effects, such as a decreased risk of infection as measured by basal immunoglobulin A (IgA) (27). However, if exercise is intense or if nutrient status is poor due to inadequate intake, the stress may have negative effects (13,30). For example, bouts of strenuous exercise in children have been shown to induce transient effects in the immune system (salivary IgA and cortisol) which, when suppressed for longer periods, may increase a child's risk of infection (13).

As very little is understood about how pregame snacks impact exercise performance in children, this study explored how three different pregame snacks—which varied in macronutrient composition, GI, and nutrient density—impacted exercise intensity, physiological markers of stress, and post-match perceptions of fatigue in young soccer players. We hypothesized that consumption of a high-sugar, high-GI snack would result in lower post-match blood glucose and salivary IgA as well as elevated cortisol and post-game fatigue.

Methods

Participants

Male and female soccer players ($n = 115$) aged 7–11 years were recruited from local youth indoor soccer leagues in Acton, Massachusetts and 79 successfully completed the study protocol (9.1 ± 0.8 yr; 68% female). Team coaches were initially recruited to have their teams participate in the study. The study design and aims were explained to each team in detail. On a typical "study game day," players on a team agreed to participate in the study (range 5–10) and if the opposing team was also participating, data were obtained from players on both teams (there were no more than 16 study subjects per game). These games took place over the course of 3 months (late January–March) during the late afternoon and early evening. Exclusion criteria included children with food allergies, asthma, and/or diabetes. All participants provided written assent, and their parents signed an informed consent document approved by the Tufts University Institutional Review Board.

Pregame Procedures

All participants were asked to consume normal meals leading up to and on the study day but not to consume any foods or beverages other than water for 2 hr before arrival at the field. Subjects arrived approximately 1 hr before their game start time. Anthropometric measures were performed and a salivary sample was obtained from each player according to the methods described below for determination of biochemical stress markers. Blood glucose was determined by a standard finger prick procedure. Participants were randomized upon arrival (not stratified by other factors) to consume an isocaloric snack bar before the match and were fitted with an accelerometer. Children only participated on one study occasion and consumed only one study snack. Children also filled out a brief dietary survey on the foods they ate the day before during this time period.

Anthropometrics. Stature was measured in triplicate to the nearest eighth of an inch using a portable stadiometer (Shorr Infant/Child/Adult Height/Length Measuring Board; Healthometer, Boca Raton, FL) with the head in the Frankfurt plane made with a right angle height procedure (32). Body mass was measured in triplicate in light clothing without shoes to the nearest 0.5 lb on a digital scale (SECA Bella model 840; Hanover, MD). Inches and pounds were converted to metric units using standard conversations for analysis. Weight status was determined from age- and sex-specific BMI cut-offs according to the Centers for Disease Control growth charts (9). In accordance with current guidance, a z-score of < 5 percentile is underweight, between the 5–85th percentile is normal weight, between the 85–95th percentile is overweight, and > 95th percentile is obese.

Salivary Cortisol and Immunoglobulin A (IgA). Unstimulated, whole saliva samples were collected using pre-weighed (Mettler Toledo Balance Scale, Thornton Inc, Bedford, MA) Salimetrics Oral Swabs (SOS; Salimetrics, State College, PA) pre- and post-game for each subject. Subjects were asked to rinse their mouth with water approximately 10 minutes before the saliva collection. Subjects placed the SOS in their mouths for 1.5 minutes. Collection swabs were immediately placed in pre-weighed storage tubes and refrigerated until they could be weighed. The same procedure was repeated directly after the soccer game. After weighing the tubes/swabs to estimate wet saliva weight, the samples were stored at –40 °C until analysis.

Samples were assayed in duplicate for both salivary cortisol and IgA (s-IgA) concentrations using enzyme immunoassay (EIA) kits (Salimetrics). Samples with duplicate values that had coefficients of variation > 15% were subject to repeat testing ($n = 3$). To calculate s-IgA secretion rate, the saliva flow rate was determined by dividing the weight of saliva by collection time, and then the absolute s-IgA concentration was multiplied by the flow rate. Assay sensitivity is 2.5 µg/mL and < 0.007 µg/dL for IgA and cortisol, respectively.

Blood Glucose. The Accu-Chek Aviva blood glucose meter and test strips (Roche Diagnostics, Indianapolis, IN) were used to measure capillary blood glucose in the study participants using a simple finger stick (Accu-Chek Safe-T-Pro Plus). Right after the finger stick, each child applied their finger to the test strip. The test strip was immediately fed into the glucometer after which a blood glucose result was obtained within 5 seconds. Glucometer readings yield 95% accuracy within ±15 mg/dL of a reference at glucose concentrations less than 100 mg/dL and within ±15% at glucose concentrations greater than or equal to 100 mg/dL. Capillary blood glucose readings in children have been found to be representative of venous samples taken by venipuncture (47).

Snacks. One hour before the start of the game, participants were asked to consume a palatable and isocaloric snack bar (165–170 kcal) consisting of either: 1) raisins, white flour, brown sugar, butter, quick-cooking oats, honey, egg whites, ready-to-eat rice cereal, and peanuts (low/medium-GI of 64); 2) graham crackers, peanut butter, honey, and marshmallow crème (medium-GI of 70); or 3) ready-to-eat rice cereal, corn meal, wheat flour, vanilla extract, caramel sauce, and marshmallow crème (high-GI of 83). Snacks 1 and 2 had similar percentages of carbohydrate, protein, and fat but varied in nutrient density. As the raisin snack is at the low end of a medium-GI food, we are labeling it "low/ medium-GI (low/med)" for simplicity and to identify it as our lowest GI snack. The recipes for the snacks were developed (by H.R.) using the Nutrition Data System for Research software version 2010 (developed by the Nutrition Coordinating Center (NCC), University of Minnesota, Minneapolis, MN) for all of the nutrient analysis except the flavonoid values (USDA Database for the Flavonoid Content of Select Foods Release 2.1 January 2007, Nutrient Data Laboratory, Agriculture Research Service, Beltsville, MD). The snack items were produced at Community Servings Kitchen in Jamaica Plains, MA. For specific macronutrient and nutrient content breakdowns see Table 1. Children were encouraged to eat the entire snack and visual estimation (tracing/grid of original snack size) of percentage of snack consumed was noted.

Dietary Recall. Children answered a short self-administered dietary recall questionnaire (Block One-Day Recall, Block Dietary Data Systems). This questionnaire is intended to measure food groups as well as consumption of calorie-dense, nutrient-poor foods in youth 8–17 years of age for the 24 hours before administration (15,21,24,37). Fruit and vegetable intake was used as a measure of diet quality.

Accelerometry. The Actigraph model 7164 accelerometer (Actigraph, LLC; Pensacola, FL) was worn just before and throughout the game to document the soccer match activity level of each child. Detailed methods are presented elsewhere (46). Briefly, monitors were calibrated (using the manufacturer's calibrator, model CAL71) and initialized the day before they were distributed. Epochs of 1 s were specified. Staff placed the accelerometer over the right hip of each child on an elasticized belt. Children were also instructed on the proper placement and the importance of consistently wearing the monitor over the game/study period. Monitors were programmed to begin measuring 1 hr before game start time. Game start and stop times were noted.

Accelerometer data were downloaded and imported into a SAS (Version 9.2, Cary, NC) data reduction program. Data reduction steps were followed according to Masse (35) and adapted from the NHANES protocol (52) and described in detail previously (46). For the analyses presented here, activity levels were based on the value of the accelerometer count at each second. These cut-offs were based on Puyau et al. (44), where their measurement of 60-s epochs in children were divided by 60 resulting in the following cut-offs for the current study: sedentary = counts < 13; light activity = counts 13–52; moderate activity = counts 53–136; vigorous activity = counts > 136. Across valid wear-time for each subject, average counts/min were calculated, along with number of minutes and percent of time spent in sedentary, light, moderate, and vigorous activity.

Table 1 Nutrient Breakdown of the Three Pre-exercise Snacks by Glycemic Index (GI) Given to Children 1 Hr Before a Soccer Match

	Low/ Med-GI	Med-GI	High-GI
Glycemic Index	64/92	70/100	83/118
Glycemic Load	18/26	19/27	32/45
Calories (kcal)	170	168	167
Carbohydrate (% kcal)	68.3	64.8	91.9
Protein (% kcal)	6.4	7.6	2.8
Fat (% kcal)	25.4	27.6	4.9
Added Sugars (g)	10.0	16.1	31.5
Sodium (mg)	49	176	142
Potassium (mg)	159	79	32
Fiber (g)	1.5	1.4	0.5
Vitamin C (mg)	0.6	0.1	2.7
Vitamin E (IU)	1.0	1.0	1.0
Calcium (mg)	28	24	34
Magnesium (mg)	20	20	7
Selenium (μg)	4.8	4.2	1.8
Carotenoids (μg)	15	14	40
Flavonoids (mg)	13.9	1.3	trace

Note. Glycemic Index (GI) and glycemic load are reported relative to pure glucose or white bread. Low/Med-GI = low/medium GI; Med-GI = medium GI

Game-Time Procedures

The games consisted of two 25-min periods separated by a 5-min break. The accelerometers stored data at 1-s intervals throughout the entire match. Participants were given their own bottle of prebottled water (Poland Springs 591.5 ml, Nestle Waters North America) and allowed to drink ad libitum throughout the match. Total volume of water consumed was noted for each participant. The participants were asked not to drink other types of beverages.

Postgame Procedures

Post-match (within 10 min of game-time completion), a second saliva sample was collected along with a finger stick for blood glucose determination. The children were also asked to answer a brief investigator-administered Perceptions of Exercise Fatigue Questionnaire.

Perceptions of Exercise Fatigue Questionnaire. The fatigue questionnaire incorporated the validated Subjective Exercise Experiences Scale (SEES), which has been validated to measure positive well-being, psychological stress, and subjective indicators of fatigue (34). The survey asks 12 questions about feelings of fatigue utilizing a Likert-type scale with 1 corresponding to *not at all* to 7 corresponding to *very much so*. We also incorporated an additional 4 questions regarding how different parts of their body felt and were answered as *yes* or *no*: 1) stomach (aches, sick, cramps); 2) head (dizzy, clear, headache); 3) legs (weak, heavy); 4) chest or lungs (hurt, out of breath). These were analyzed individually and as a body parts composite score (total of answers that were "yes").

Analyses

Children who consumed less than 75% of the snack or who reported eating within the 2 hr before arrival were not included in the analyses. Comparisons of pre- to post-exercise changes in blood glucose, IgA, cortisol, exercise intensity, and fatigue between the 3 conditions (snacks) were initially conducted by use of Kruskal-Wallis tests due to the normality of the variables. Potential sex differences were analyzed using independent samples *t* test. Pearson's product moment correlation analyses were used to examine relationships of interest. Analysis of covariance was used to examine the association between the pre-exercise snack consumed and biochemical outcomes separately (glucose, cortisol, and IgA) after controlling for sex, age, BMI z-score, dietary quality, game-time water consumption (in ml), and game exercise intensity (minutes in moderate-to-vigorous physical activity, or MVPA). Spearman rank-order correlations were used to estimate the relationship between the self-report of fatigue and objectively measured variables. Level of significance was set at 0.05.

Results

Of the 115 participants, 97 ate at least 75% of the assigned study snack and 26 children reported eating within the 2 hr before arrival (10 boys, 16 girls), so a final sample size of $n = 79$ was obtained. Table 2 presents the age and anthropometric data of these 79 children by snack group. Overall, 3.5% were underweight, 74.8% were normal weight, 15.7% were overweight, and 6.1% were obese, with weight status not differing by snack group.

Diet

Dietary intake data are shown by snack group in Table 2. There were no differences in the dietary intake by snack group or by sex (data not shown). Children consumed an average serving of fruits and vegetables of 3.0 ± 1.5/d (not including potatoes). Water intake during the games did not differ between groups (mean ± *SD*, 247.0 ± 125 ml).

Exercise Intensity

Figure 1 depicts accelerometry counts per minute and percent time spent in light, moderate, and vigorous activ-

Table 2 Subject Descriptive, Activity, and Dietary Intake Information

	Low/Med-GI (n = 24)	Med-GI (n = 30)	High-GI (n = 25)
Age (years)	9.0 ± 0.8	9.3 ± 0.7	9.1 ± 0.9
Height (cm)	137.1 ± 6.7	138.8 ± 6.7	137.8 ± 7.2
Weight (kg)	33.9 ± 6.5	34.1 ± 5.7	32.9 ± 6.9
BMI (kg/m^2)	17.9 ± 2.3	17.6 ± 2.5	17.1 ± 2.4
Game activity (min)	27.5 ± 5.3	25.5 ± 5.3	26.5 ± 5.3
Calories (kcal)	1490 ± 525	1545 ± 514	1479 ± 738
Carbohydrates (% kcal)	56.2 ± 10.7	51.9 ± 6.5	54.4 ± 9.0
Protein (% kcal)	15.8 ± 3.2	16.8 ± 3.7	16.2 ± 3.3
Total Fat (% kcal)	30.0 ± 8.6	33.3 ± 5.4	31.5 ± 6.8
Saturated Fat (% kcal)	11.4 ± 3.1	12.5 ± 2.8	11.8 ± 3.3
Vegetable (srv)	1.3 ± 0.9	1.2 ± 0.8	1.2 ± 0.9
Fruit (srv)	2.2 ± 1.1	1.9 ± 1.2	2.0 ± 1.3
Whole grains (g)	28.4 ± 17.0	22.7 ± 19.8	25.5 ± 22.7
Dairy (srv)	2.5 ± 1.2	2.7 ± 0.9	2.3 ± 1.7
Dietary Fiber (g)	14.6 ± 4.9	13.5 ± 5.6	14.2 ± 7.1

Note. Means ± *SD*. Game activity = total game time activity spent in light, moderate and vigorous activity combined (total possible minutes = 50). Servings for fruits, vegetables and dairy were calculated as cup equivalents. Total vegetable servings does not include potatoes. No significant differences between males and females.

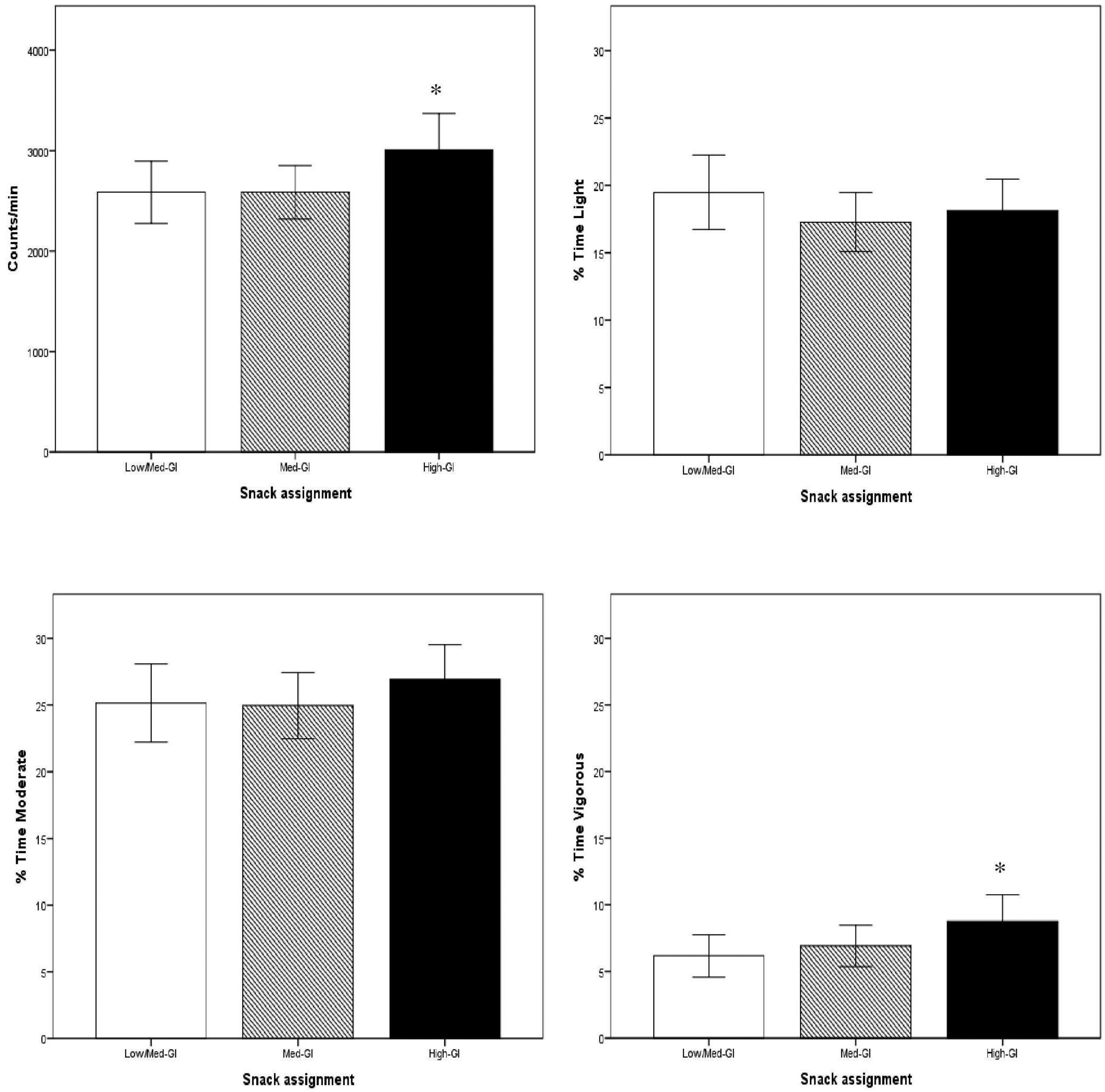

Figure 1 — Game-time total counts per minute and % time spent in light, moderate, and vigorous activity as measured by accelerometry by glycemic index (Low/Med-GI, Med-GI, and High-GI) snack group ($n = 79$). *Different from Low/Med-GI and Med-GI group combined, $P<.05$.

ity for the three different snack groups. There were no significant differences in the amount or type of activity between the three snacks groups. However, if the lower GI snack groups with higher protein and fat content are combined (raisin- and peanut butter-based), there are differences between these groups for counts/min and percent time spent in vigorous activity whereby the cereal-based snack group (higher carbohydrate and higher GI) is more active on a vigorous level (Figure 1; $P < .05$). There were no sex differences in total counts or percent time in sedentary, light, or vigorous activity; however, girls spent a higher percentage of time in moderate physical activity compared with boys (26.5% ± 7.3% vs. 23.0% ± 5.6%; $P < .01$), as described previously (36).

Biological Markers

Overall, post-exercise blood glucose ($P < .001$) and cortisol ($P < .05$) increased and IgA levels decreased from pregame values ($P < .001$). Table 3 presents the results of these biological markers with respect to snack group. There were no significant differences between the three snack groups post-exercise or in the change in levels pre- to post-exercise for these biomarkers ($p > .05$). The pre-exercise snack did not predict post-exercise levels of any of these markers after controlling for covariates. However, BMI z-score (Beta = –4.52, $P = .036$) was associated with pre- to post-game changes in blood glucose, whereby children with a higher BMI z-score had less post-exercise elevation in blood sugar.

Subjective Fatigue

There were no significant associations between the pre-exercise snack consumed and the SEES subjective feelings of fatigue post-game. However, participants who reported feeling sick, having a cramp, having weak legs, having their chest and lungs hurt, or those who reported "yes" more often on the body parts composite were more likely to have eaten the cereal-based snack (high-GI fatigue score = 13.9 ± 7.1) compared with consuming the raisin- and peanut butter-based ones (lower-GI fatigue score = 11.6 ± 5.9; $P < .05$). There were no associations between these indices (how specific body parts feel) and accelerometry total counts or percent time spent in different intensities of activity. However, decreases in post-exercise IgA were associated with more fatigue of actual body parts (body part composite score; Spearman's rho = –0.201, $P < .05$).

Discussion

The snacks formulated for this study were designed to emulate popular commercially available pre-exercise snacks, which often vary in GI, macronutrient content, and nutrient density (added sugar and micronutrient content). Consumption of the different snacks did not affect blood sugar or salivary biomarkers of stress following a soccer game in young children, nor was there a clear effect of one pre-exercise snack with regard to macronutrient or overall nutrient density on physical activity intensity during a soccer match. However children consuming the high-GI snack (higher sugar and carbohydrate) exercised more intensely when compared with the 2 lower-medium-GI snacks (higher in protein and fat) combined**.** Even though one 50-minute soccer match was not an extensive exercise period, we did find that it caused elevations in post-exercise glucose and cortisol and decreases in salivary IgA in these young children, independent of snack consumed.

Both the glycemic index and nutrient density of the snacks should be considered with respect to exercise intensity and stress outcomes. The range of glycemic indices of the snacks ranged from 64 to 83, with 2 of the snacks having a moderate GI (64 and 70, for the raisin and peanut butter snacks, respectively) and the highest glycemic index snack (cereal) having a high GI of 83. Based on studies in adults, eating a high-GI snack would cause a quick rise in blood sugar followed by a surge in insulin, which subsequently causes blood sugar to drop (14). However, exercise complicates this response as it causes a natural rise in circulating glucose to fuel activity. It appears that all the snacks contributed to a similar blood sugar rise that was apparent immediately following exercise. Other studies have shown that blood glucose goes up slightly with exercise in those who are adapted to the activity whereas those who are "untrained" may have a steady decline in blood sugar over the course of the exercise bout (2,7,11,12,20,26,40). It may be that the length of the soccer match, and the amount of time engaged in MVPA, was not long or intense enough to decrease post-exercise blood sugar levels. Interestingly, the higher the BMI of the child, the less of an increase in blood sugar following the match, which may be due in part to these children engaging in less MVPA or indicative of blood sugar levels beginning to drop due to greater glucose utilization for the given amount of activity (46). Thus, blood sugar responses to exercise must take into careful consideration other factors beyond pre-exercise food intake.

Table 3 Biological Markers Pre- and Postgame for Children Consuming Different Preexercise Snacks

	Low/Med-GI (*n* = 24)			Med-GI (*n* = 30)			High-GI (*n* = 25)		
	Pre-Game	Post-Game	Change	Pre-Game	Post-Game	Change	Pre-Game	Post-Game	Change
Glucose (mg/dl)	94.0 ± 10.5	106.2 ± 16.7	11.9 ± 19.3**	93.1 ± 14.3	108.1 ± 16.4	15.0 ± 17.8**	101.8 ± 11.9	113.5 ± 23.5	11.8 ± 27.4*
Cortisol (µg/dl)	0.15 ± 0.15	0.24 ± 0.25	0.04 ± 0.12+	0.18 ± 0.17	0.19 ± 0.17	0.01 ± 0.09	0.16 ± 0.15	0.25 ± 0.24	0.05 ± 0.13+
IgA (µg/ml)	89.7 ± 36.5	66.6 ± 37.1	–11.5 ± 14.5**	104.9 ± 69.0	79.0 ± 32.6	–13.9 ± 28.5*	85.2 ± 49.8	79.6 ± 44.4	-5.7 ± 19.1

Note. No significant differences between the 3 snack groups post-exercise or in the change in levels pre- to post-exercise for these biomarkers. Significant pre- to post-game change within snack groups, *$P < .05$, **$P < .01$, +$P < .10$

Independent of the snack consumed, there was a pre- to post-exercise fall in salivary IgA and a rise in salivary cortisol, but there was a large variability in these responses as evidenced by their large standard deviations. Few studies have assessed the effect of exercise on salivary cortisol (16) and IgA in children (19) but these studies seem to indicate that levels of both increase post-exercise. Cortisol is a stress hormone and is associated with an increase in blood sugar (51) as well as free fatty acid release and possibly the utilization of free fatty acids during exercise. Compared with adults, free fatty acids may play a more important fuel source during exercise in children (4). Although we cannot determine the fuel sources used by the children, it would not be surprising if the children relied heavily both on free fatty acids and glucose for their energy sources as the soccer matches examined in this study were interspersed with high- and low-intensity activity.

In these children, a standard soccer match with an average time of moderate-to-vigorous intensity exercise is intense enough to cause perturbations in salivary IgA, but it is unclear how long this perturbation lasts after the exercise bout. It should also be noted that this decrease in post-exercise IgA was associated with more fatigue of specific body parts in children. A comprehensive review on mucosal immunity by Gleeson et al. (22) indicated that IgA decreases with intensive exercise. Similar to our findings in children, Moreira et al. (36) demonstrated that salivary IgA decreases post-exercise in professional soccer players and is inversely related to their rate of perceived exertion.

With respect to dietary factors and stress responses, the literature is scant. Pre-exercise carbohydrate feedings and flavonoid supplementation studies were not found to impact salivary IgA (1,5,38). In the current study, the type of nutrient density varied among the three snacks; for example with regard to antioxidant content, the more nutrient-dense raisin-based snack had the highest flavonoid content, but the cereal-based high-sugar snack contained the highest vitamin C and carotenoid content, such that we cannot tease out any potential effects of specific antioxidants per se. The impact of dietary nutrients on salivary stress markers necessitates more careful research.

Separate from the objective physiological measurements of stress, subjective feelings of fatigue were greater in children who consumed the cereal-based snack. As the snack was consumed in the hour before activity, this high sugar, high-GI snack was likely to be more quickly digested and potentially enabled greater activity intensity during the match. We did detect higher exercise intensity in this group compared with the other 2 snack groups, and more activity, in turn, could cause a greater sense of fatigue in children. Unfortunately, we do not know what happened during the actual match with circulating glucose; however, pre- to post-game glucose in the cereal-based snack group was no different than the other groups.

There are several limitations of this study worth noting. This study occurred in a natural sporting environment where children were given just one pre-exercise snack amid other habitual dietary factors, and hydration was only monitored during the match. In addition, these children were playing a soccer game so the levels of activity will vary in accordance with many other factors—coaching, motivation, agility, opponents, and other activities in which they are engaged. Finally, the reported estimates of dietary patterns of the children closely reflected those of national data-sets (53): low in fruits and vegetables with roughly half of their calories from carbohydrate and 30% from fat, though these were only estimates based on a guided recall of the food the children ate yesterday. More careful control of other dietary factors will be important in future investigations.

Conclusion

Dietary macronutrient composition, nutrient density, hydration, and meal timing are all important in impacting exercise performance in adults but it is less clear how these factors impact children participating in recreational sports. Our results indicate preliminarily that consumption of a high-sugar, high-GI snack is associated with game physical activity intensity but also results in post-exercise fatigue in children. It appears that there are subtle perturbations in blood sugar, stress measures, and fatigue following a recreational soccer match; however, consumption of 3 different pre-exercise snacks which varied in both macronutrient and nutrient density did not have a major impact on these parameters. Finally, our study reveals some of the challenges to studying the effects of foods and exercise among young children in a natural setting. Future investigations are warranted to further explore the effects of pre-exercise snacks, especially those high in added sugars, which ultimately could have negative effects on longer duration exercise performance, stress and fatigue in children.

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