Effect of Carbohydrate Ingestion on Blood Glucose Concentration and Women’s Gymnastics Performance

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Abstract
The intent of this study was to report the effect of carbohydrate (CHO) ingestion during a women’s collegiate gymnastics competition on: 1) Blood glucose concentration; 2) Post-competition respiratory exchange ratio; 3) Gymnastics performance score. Thirteen college division three (D III) gymnasts volunteered to participate in a two-trial (placebo and CHO supplement) within-subjects study involving the ingestion of 120 ml of a 6.5% CHO solution and a placebo matched for volume, electrolyte content, color and flavor at 20-minute intervals during pre-season competition. Resting and recovery oxygen consumption (VO₂) and respiratory exchange ratio (R-value) were measured using Douglas bag technique. Oxygen consumption was significantly greater during recovery, yet independent of drink. Blood glucose was measured at six time points with fingertip venous blood sample and an Ascensia Contour Monitor. Rate of increase blood glucose was greater with CHO supplementation. Blood glucose was 19% greater in the second and third interval and 21% greater in the fourth interval with CHO. Competition scores were not significantly different between condition, although average floor score was 0.30 better in the carbohydrate (9.17 ± 0.46) than placebo (8.87 ± 0.73) trial. This difference was close to significance (t = 2.035, df = 8, p = .076).

Keywords: Women’s gymnastics, Glucose supplementation, Respiratory exchange ratio, Fuel utilization, Sports drinks

Introduction
The human body relies on various metabolic pathways and regulating hormones to maintain blood glucose at homeostasis. Blood glucose homeostasis is necessary for proper functioning of the peripheral and central nervous systems (Welsh, Davis, Burke, & Williams, 2002), and is of great importance during exercise. The physiological challenge of maintaining blood glucose escalates during exercise. This is due to the increase in glucose uptake from the blood into the cells for use in muscular contraction (Coggan, 1991). Continued exercise will cause blood glucose to decrease and possibly impair the functioning of the central nervous system, causing dizziness, weakness and/or hunger. Central nervous system symptoms could be accompanied by physical responses such as decreased work output or complete termination of activity (Kayser, 2003).

It is well established that carbohydrate supplementation during exercise can enhance performance by delaying fatigue. Extensive research exists on the use of carbohydrate supplementation during endurance events. Earlier studies involving running (Wilbur & Moffatt, 1992) and cycling (Wright, Sherman, & Dernbach, 1991) have found a 29% and 32% increase in time to fatigue with carbohydrate
ingestion, respectively. Studies examining endurance events with an anaerobic component (Fritzsche et al., 2000) found anaerobic power to decline least with carbohydrate and water supplementation (7.4%) compared to a placebo (14.5%). In addition to these endurance results, research on intermittent high-intensity exercise found carbohydrate supplementation to delay time to fatigue by 37% when shuttle-running (Welsh et al., 2002) and 45% when cycling (Davis, J.M., Jackson, D.A., Broadwell, M.S., Querary, J.L., & Lambert, 1997). Interestingly, recent research has shown performance improvements with tasting of carbohydrate drink (Carter, Jeukendrup, & Jones, 2004; Jeukendrup, Rollo, & Carter, 2013). Although the mechanisms behind the improved performance outcomes with CHO supplementation are not yet clearly defined, the majority of researchers contend that carbohydrate supplementation allows for optimal levels of blood glucose, insulin and metabolites of glycolysis and muscle contraction.

Carbohydrate supplementation directed specifically toward the sport of gymnastics is lacking. It is recommended that gymnasts consume a meal containing primarily carbohydrates three to four hours prior to the event and ingest 4 to 6 ounces of a 6% to 8% carbohydrate solution every 15 to 20 minutes during the event (Jemmi, 2011). Nutritional scientific experiments designed specifically for gymnastics are needed. The intent of this study was to determine if carbohydrate supplementation during a women’s National Collegiate Athletic Association (NCAA) gymnastics competition would allow blood glucose to be maintained and benefit gymnastics performance as it has various other sporting events.

Energy maintenance throughout a typical four-hour gymnastics meet is a critical concern, especially for the all-around gymnast who must compete on all four events. Due to performance anxiety, the pressure of competition, or time constraints of the meet, gymnasts often fail to properly fuel and refuel their bodies. Some gymnasts avoid energy intake before and during the meet entirely, while others may consume poor food choices (Jemmi, 2011).

It was hypothesized that the carbohydrate ingestion trial would result in a) significantly greater blood glucose levels, b) significantly higher (better) scores during gymnastics competition and c) higher post-competition respiratory exchange ratio (R-values) than the placebo trial.

Methods

Sample Selection

Thirteen trained gymnasts (age = 19.8 ± 1.2 yrs, height = 157.89 ± 5.0 cm, weight = 59 ± 5.0 kg) from the University’s Women’s Gymnastics Team participated in this study. The skill level of the gymnasts ranged from Junior Olympic Levels 8 through 10. Three of the gymnasts performed in the all-around competition (competed in all four events), two performed on three events, seven performed on
two events and one performed on one event. Each participant was informed of the risks associated with the study and signed a consent form approved by Universities Institutional Review Board.

**Research Design**

The study involved two experimental crossover trials (gymnastics meets), designed to follow the format of a women’s collegiate dual gymnastics competition, during which subjects received either a carbohydrate or placebo beverage. The carbohydrate beverage consisted of 6.5 g of carbohydrate dissolved in 120 ml of water. The placebo beverage was matched for volume, flavor, color and electrolyte content (GU2O, GUSports Laboratory, Berkeley, CA). The experimental trials were separated by 14 days that included only six practice sessions.

The participants of this study were randomly divided into two groups (teams). The teams were matched for total number of participants and number participating on each event. This was done such that each event would take approximately the same amount of time to compete. Team one had six participants: five performed on the vault, four on the uneven bars, three on the balance beam and five on the floor. Team two had seven participants: four performed on the vault, five on the uneven bars, four on the balance beam and four on the floor. The rotation for each team was randomly chosen and maintained for the second trial. The beverage chosen for each team was done randomly and blinded such that the subjects were unaware of the contents of the beverage at each trial.

Participants were informed of the dietary regulations and the sequence of events for each trial. Subjects were instructed to complete a two-day diet log prior to the first simulated gymnastics competition. The log contained information regarding all foods and beverages consumed. Carbohydrate, protein and fat contents were listed as well as total kcals. Individuals replicated the carbohydrate, protein, fat and kcal intake two days preceding the second trial. Participants were asked not to consume food or beverage after 10:00 PM the night before each trial. At 8:00 AM of trial day, gymnasts consumed a predetermined meal consisting of approximately 370 kcals (~71% carbohydrate, ~13% protein and ~16% fat) and 500 ml of water. Workload was also closely monitored. Participants replicated the events practiced and volume of skills performed the two days prior to each trial (see timeline in Table 1).

**Instruments**

Pre-event expired gas was collected in Douglas bags for two minutes at approximately 10:20 AM. The classic Douglas bag technique (Taylor, Buskirk, & Henschel, 1955) allowed us to collect expired air samples from all the participants at similar time points pre- and post-competition. All Douglas bags were checked for leaks, and expired air was analyzed as described below. Post-event expired gas was collected in the same manner between 10 and
Table 1. Time line for Pre-Event, Warm-up and Competition Procedures

<table>
<thead>
<tr>
<th>Time</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-Event Procedures</strong></td>
<td></td>
</tr>
<tr>
<td>8:00 a.m.</td>
<td>Consume Meal and 12 fluid oz. H₂O</td>
</tr>
<tr>
<td>9:45 a.m.</td>
<td>Arrive to lab</td>
</tr>
<tr>
<td>10:00 a.m.</td>
<td>Height, Weight Resting Heart Rate and blood glucose</td>
</tr>
<tr>
<td>10:20 a.m.</td>
<td>Begin Resting Expired Gas Collection</td>
</tr>
<tr>
<td>11:20 a.m.</td>
<td>1st Drink Stretch</td>
</tr>
<tr>
<td><strong>Warm-up Procedures</strong></td>
<td></td>
</tr>
<tr>
<td>11:40 a.m.</td>
<td>2nd Drink Warm-up 1st event</td>
</tr>
<tr>
<td>12:00 p.m.</td>
<td>3rd Drink Warm-up 2nd Event 3rd Blood Glucose</td>
</tr>
<tr>
<td>12:20 p.m.</td>
<td>4th Drink Warm-up 3rd Event</td>
</tr>
<tr>
<td>12:30 p.m.</td>
<td>4th Blood Glucose Warm-up 4th Event 5th Drink</td>
</tr>
<tr>
<td><strong>Competition Procedures</strong></td>
<td></td>
</tr>
<tr>
<td>1:00 p.m.</td>
<td>Compete 1st Event</td>
</tr>
<tr>
<td>1:20 p.m.</td>
<td>6th Drink</td>
</tr>
<tr>
<td>1:30 p.m.</td>
<td>Compete 2nd Event</td>
</tr>
<tr>
<td>1:40 p.m.</td>
<td>7th Drink 5th Blood Glucose</td>
</tr>
<tr>
<td>2:00 p.m.</td>
<td>8th Drink Compete 3rd Event</td>
</tr>
<tr>
<td>2:20 p.m.</td>
<td>9th Drink</td>
</tr>
<tr>
<td>2:30 p.m.</td>
<td>6th Blood Glucose Compete 4th Event</td>
</tr>
<tr>
<td>2:40 p.m.</td>
<td>10th Drink</td>
</tr>
<tr>
<td>3:00 p.m.</td>
<td>Begin Recovery Expired Gas Collection and Heart Rate</td>
</tr>
</tbody>
</table>
15 minutes following the completion of the subjects’ final event. Expired gas samples were analyzed for oxygen and carbon dioxide concentration using a VacuMed Metabolic Cart (Vista mini-CPX) and Turbofit 5.0 software. A rubber stopper and tubing of the Douglas bag was attached to the metabolic cart and small sample of expired air (200 ml) was used to determine oxygen and carbon dioxide percentages. Percentages were recorded and respiratory exchange ratio was calculated using the standard formula (Hopker, Jobson, Gregson, Coleman, & Passfield, 2012). The contents in the Douglas bag were then steadily drawn through a flow meter (Harvard Apparatus, Kent, UK) to determine volume. This value was converted to STPD conditions and used to calculate volume of oxygen consumed and volume of CO₂ produced.

Resting and recovery heart rates were taken on each subject. A Polar Heart Rate (model FT1) watch was pre-set to record heart rate every five seconds. These heart rate data were later downloaded and averaged.

Blood glucose was tested with an Ascensia Contour Blood Glucose Monitoring System. This system is traditionally used for monitoring the blood glucose of diabetic patients. Use of the monitoring system is considered a simple, safe and effective way to detect the blood glucose level of diabetic patients. Basal blood glucose was assessed at 10:00 AM. Additional testing took place at approximately 11:30 AM and 12:10, 1:00, 1:30 and 2:30 PM. Subjects performing only on the uneven bars and vaulting table (n = 2) were not tested a sixth time because their participation ended at 1:30 PM.

Additional Data Collection

Scores on each of the four apparatus were determined by two Level 10 Junior Olympic qualified judges. Collegiate gymnastics is based on Level 10 Junior Olympic rules, which include minor modifications to better suit the needs of a collegiate gymnast. The judges calculated each score by subtracting the necessary deductions from the routine’s start value. The start value for the uneven bars, balance beam and floor exercise is a 9.5. Gymnasts perform up to 0.5 of bonus skills and combinations to earn a 10.0 start value. Each vault is designated its own start value based on its level of difficulty. If an incorrect start value was posted during the simulated competition, an inquiry was submitted by the coach and adjustments were made if deemed appropriate by the judge.

Data Analysis

All statistical analyses were performed using SPSS for Windows (version 22). An alpha level of 0.05 was used for all tests. Two-way within-subjects analysis of variance (ANOVA) was used to analyze heart rate, blood glucose concentration, oxygen consumption and respiratory exchange ratio data. The main effect of time and beverage and the interaction between the two were examined. If significant differences were found, a least significant
difference follow-up analysis was conducted.

**Results**

There were no significant differences in laboratory or gymnasium temperature, humidity, or barometric pressure between the two trials.

**Heart Rate**

Resting heart rate was recorded when subjects arrived to the laboratory, and recovery heart rate was recorded 10 to 15 minutes following the completion of the subjects’ final competitive event. Mean resting and recovery heart rates were compared using 11 subjects, as recovery data were not obtained on two individuals due to loss of signal communication to receiver (Polar HR monitor watch) from two gymnasts. The mean resting heart rate was 66.8 ± 12.5 b · m⁻¹ and 69.3 ± 12.0 b · m⁻¹ for the carbohydrate and placebo trial respectively. The mean recovery heart rate was 93.1 ± 11.3 b · m⁻¹ and 89.3 ± 9.5 b · m⁻¹ for the carbohydrate and placebo trial respectively (see Table 2).

A two-way within-subjects ANOVA indicated that the main effect time was significant (\(F_{(1, 10)} = 164.225, p < .05\)). Recovery heart rate was significantly higher than resting heart rate for both trials. The main effect of beverage was not significant (\(F_{(1, 10)} = .099, p = .759\)). A significant interaction was not found between time and beverage (\(F_{(1, 10)} = 1.980, p = .190\)).

**Results for Blood Glucose Concentration**

Blood glucose data were analyzed at six time intervals for 11 subjects and five time intervals for 13 subjects. Two individuals,

<table>
<thead>
<tr>
<th>Subject</th>
<th>Resting heart rate (bpm)</th>
<th>Recovery heart rate (bpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Carbohydrate</td>
<td>Placebo</td>
</tr>
<tr>
<td>1</td>
<td>65</td>
<td>71</td>
</tr>
<tr>
<td>2</td>
<td>82</td>
<td>77</td>
</tr>
<tr>
<td>3</td>
<td>66</td>
<td>62</td>
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<tr>
<td>4</td>
<td>79</td>
<td>59</td>
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<tr>
<td>5</td>
<td>85</td>
<td>79</td>
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<td>6</td>
<td>59</td>
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<td>10</td>
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<td>67</td>
</tr>
<tr>
<td>11</td>
<td>59</td>
<td>90</td>
</tr>
<tr>
<td>M</td>
<td>66.82</td>
<td>69.23</td>
</tr>
<tr>
<td>SD</td>
<td>12.50</td>
<td>12.03</td>
</tr>
</tbody>
</table>

*Note.* n = 11 due to loss of signal communication to receiver from two gymnasts.
competing on only vault and bars, finished the competition at 1:30 PM and therefore were not tested during the final collection period. The average blood glucose concentration at rest for 11 subjects was similar for the carbohydrate and placebo trial (87.8 ± 10.7 mg · dl⁻¹ and 89.6 ± 11.0 mg · dl⁻¹ respectively). Blood glucose values were different between the carbohydrate and placebo trial at the second (108.8 ± 18.7 mg · dl⁻¹ and 91.4 ± 6.5 mg · dl⁻¹), third (114.5 ± 24.5 mg · dl⁻¹ and 96.1 ± 8.7 mg · dl⁻¹) and fourth (117.0 ± 24.7 mg · dl⁻¹ and 96.6 ± 10.3 mg · dl⁻¹) collection point, respectively. This represents 19% greater blood glucose in the second and third interval and 21% greater blood glucose in the fourth interval with carbohydrate supplementation. Blood glucose concentration was not different between the carbohydrate and placebo trial at the fifth (114.4 ± 18.7 mg · dl⁻¹ and 110.1 ± 32.6 mg · dl⁻¹) and sixth (120.3 ± 13.6 mg · dl⁻¹ and 121.0 ± 29.3 mg · dl⁻¹) collection point, respectively.

A two-way within-subjects ANOVA for the six time intervals revealed significance for the main effect time ($F_{(5, 50)} = 8.873, \eta = .470, p < 0.05$). Blood glucose concentration was significantly higher after the competition than prior to it. Although the main effect of beverage was not significant ($F_{(1, 10)} = 8.873, p = .139$), a significant interaction was found between time and beverage ($F_{(5, 50)} = 3.027, \eta = .232, p < .05$). This indicates that the carbohydrate trial elicited greater blood glucose concentrations at specific time intervals than the placebo trial. Follow-up analysis using the least significant difference showed significantly higher blood glucose concentrations for the...
carbohydrate than placebo trial at the second, third and fourth collection period (see Figure 1).

To assess the results of all subjects, blood glucose concentrations were analyzed at the first five collection points. In this manner, the two subjects that completed the competition early could be included in the analysis. Similar results were found to that of the analysis involving all 13 subjects. The average blood glucose concentration was similar between the carbohydrate and placebo trial at rest (88.8 ± 10.7 mg · dl⁻¹ and 89.4 ± 11.4 mg · dl⁻¹) and at the fifth interval (115.6 ± 17.6 mg · dl⁻¹ and 113.2 ± 30.9 mg · dl⁻¹). Average blood glucose concentration was different at the second (106.5 ± 18 mg · dl⁻¹ and 91.2 ± 8.4 mg · dl⁻¹), third (112.1 ± 23.2 mg · dl⁻¹ and 97.6 ± 10.7 mg · dl⁻¹), and fourth (119.3 ± 23.4 mg · dl⁻¹ and 98.8 ± 11.4 mg · dl⁻¹) collection point. Carbohydrate ingestion elevated blood glucose 17%, 15% and 21% greater than that of the placebo trial in the second, third and fourth interval, respectively.

A two-way within-subjects ANOVA for the five time intervals indicated a significant main effect for time ($F$ (4, 48) = 9.990, $\eta = .454$, $p < .05$). A significant main effect for beverage was not found ($F$ (1, 12) = 4.343, $p = .059$). A significant interaction occurred between time and beverage ($F$ (4, 48) = 2.761, $\eta = .187$, $p < .05$). The least significant difference follow-up analysis indicated significantly higher blood glucose concentrations for the carbohydrate trial than the placebo trial at interval two, three and four.

Pre- and Post-Competition Oxygen Consumption and Fuel Utilization

Differences in Respiratory Exchange Ratio (R-value) were determined before and after the competition by the mean value of 12 subjects. The respiratory exchange ratio of one subject was eliminated due to a measurement error. The average pre-competition R-value was 0.87 ± 0.15 for the carbohydrate and .87 ± 0.12 for the placebo trial. The average post-competition R-value was 0.81 ± 0.09 and .75 ± 0.11 for the carbohydrate and placebo trial. Thus, the pre-competition respiratory exchange ratios were almost identical in the carbohydrate and placebo trial, but the post-competition values varied by approximately 0.06 (8%).

A two-way within-subjects ANOVA resulted in significant findings for the main effect of time ($F$ (1, 12) = 11.968, $\eta = .499$, $p < 0.01$). Post-competition respiratory exchange ratios were significantly lower than pre-competition respiratory exchange ratios. The main effect of beverage was not significant ($F$ (1, 12) = 1.634, $p = .225$). Respiratory exchange ratios were not significantly different between the trials. No significant interaction was found between the factors time and beverage ($F$ (1, 12) = 2.889, $p = 0.115$).

This indicates that the carbohydrate and placebo beverage had a similar effect on pre- and post-respiratory exchange ratios (see Figure 2).

Pre-competition oxygen consumption values were collected for two minutes in the resting state, shortly after subjects arrived to the
laboratory. Post-competition values were collected for the same time duration, but approximately 10 minutes after the subject finished her final competitive event. Pre- and post-competition oxygen consumption values were compared using the mean value of 12 subjects. The post-competition volume for one subject was not obtained at the first trial and

Figure 2. Average pre- and post-competition respiratory exchange ratios (± SEM) for the carbohydrate and placebo trial. No significant differences in R-values pre- and post-competition or with CHO supplementation. Note. n = 12.

Figure 3. Average pre- and post-competition oxygen consumption values (+SE) for the carbohydrate and placebo trial. Oxygen consumption was significantly greater in the recovery period after the competition than in the resting state prior to the competition. Significant results were not found for the main effect beverage ($F (1,11) = 0.027, p = .872$). Note. n = 12.
thus all oxygen consumption data from that subject were excluded from the report. The mean pre-competition oxygen consumption for the carbohydrate and placebo trials were $0.26 \pm 0.043 \text{ l} \cdot \text{min}^{-1}$ and $0.27 \pm 0.075 \text{ l} \cdot \text{min}^{-1}$ respectively. The post-competition values were $0.32 \pm 0.81 \text{ l} \cdot \text{min}^{-1}$ and $0.31 \pm 0.078 \text{ l} \cdot \text{min}^{-1}$ for the carbohydrate and placebo trial. Thus, oxygen consumption during recovery was approximately $0.06 \text{ l} \cdot \text{min}^{-1}$ greater for the carbohydrate trial and $0.04 \text{ l} \cdot \text{min}^{-1}$ greater for the placebo trial than in the resting state indicating greater CHO utilization during recovery.

A two-way within-subjects ANOVA indicated significant findings for the main effect time ($F_{(1, 11)} = 7.925, \eta^2 = .419, p \less 0.05$). Oxygen consumption was significantly greater in the recovery period after the competition than in the resting state prior to the competition. Significant results were not found for the main effect beverage ($F_{(1, 11)} = 0.027, p = 0.872$). Further, no significant interaction occurred ($F_{(1, 11)} = 0.191, p = 0.671$), indicating that the carbohydrate and placebo beverage did not affect pre- and post-oxygen consumption (see Figure 3).

### Gymnastics Performance

Difference in performance on the vaulting table was determined by the mean value of nine subjects. Significant differences were not found between the carbohydrate ($8.86 \pm 0.48$) and placebo ($8.88 \pm 0.59$) trial ($t = -.342, df = 8, p = .741$). Performance on the uneven bars was determined by the mean value of eight subjects. The average score was almost $0.40$ better in the carbohydrate ($8.60 \pm 0.42$) than the placebo ($8.27 \pm 0.93$) trial. This difference, however, was not significant ($t = 1.275, df = 7, p = .243$). Balance beam performance was determined by the mean value of seven participants. The average score was almost $0.10$
better in the carbohydrate (8.43 ± 1.16) than placebo (8.34 ± 0.78) trial. This difference was not significant \( t = .245, \text{df} = 6, p = .814 \). Finally, floor exercise performance was determined by the mean value of nine participants. The average floor score was 0.30 better in the carbohydrate (9.17 ± 0.46) than placebo (8.87 ± 0.73) trial. This difference was close to reaching significance \( t = 2.035, \text{df} = 8, p = .076 \) (see Figure 4). No significant differences were found when comparing the performance on vault \( t = -.342, \text{df} = 8, p = .741 \), bars \( t = -2.222, \text{df} = 7, p = .062 \), and floor \( t = -.970, \text{df} = 8, p = .331 \) between trial one and two. A significant difference was found, however, when comparing balance beam performance \( t = -2.9, \text{df} = 6, p < .05 \) in trial one and two. This indicates that on average, gymnasts performed better on the balance beam during the second simulated gymnastics competition.

### Discussion

The mean recovery heart rate, obtained 10 to 15 minutes following the final competitive event, is similar to that reported of male gymnasts of the same age. Jenni et al., (Jenni, Friemel, Lechevalier, & Origas, 2000) found the mean recovery heart rate of male gymnasts after 10 minutes of recovery to be 104.05 b · m⁻¹. This compares well to the mean recovery heart rate of the present study, 91.20 b · m⁻¹, as subjects here had up to five additional minutes to recover.

The mean blood glucose concentration was approximately 89.0 mg · dl⁻¹ before the competition and 120.0 mg · dl⁻¹ after the competition in both the carbohydrate and placebo trial. This finding is similar to that reported by Zeederberg et al., (Zeederberg et al., 1996) who reported average blood glucose concentration for soccer players after a game to be 95.4 mg · dl⁻¹ and 91.8 mg · dl⁻¹ for the carbohydrate and placebo group respectively. Similarly, Simard et al. (Simard, Tremblay, & Jobin, 1988) reported no significant difference in the blood glucose concentration of hockey players after a game between the carbohydrate and placebo trial (83.31 mg · dl⁻¹ and 89.34 mg · dl⁻¹ respectively). Although these researchers found no significant difference between groups, the post-competition values were lower than those found of gymnasts in the present study.

Although mean blood glucose was the same at the start and end of the competition in the carbohydrate and placebo trial, it varied significantly throughout the event. Blood glucose increased at a considerably faster rate in the carbohydrate trial as opposed to the placebo trial. The immediate elevation of blood glucose is beneficial, as blood glucose is needed for muscular contraction. The slower rate of blood glucose increase for the placebo trial suggests reliance on hepatic glucose production, as more time is needed for glycogenolysis to release glucose into the blood. An interesting point, however, is that both the carbohydrate and placebo trial ended with a blood glucose value of approximately
120 mg \cdot dl^{-1}. This suggests that the body’s system for regulating blood glucose was sufficiently able to accommodate for the energy demands of the athlete during the simulated gymnastics competition. The fact that the blood glucose concentration in the carbohydrate trial leveled off at 120 mg \cdot dl^{-1}, the same value that the placebo trial reached at the end of the meet, may suggest that this value is the normal and/or necessary blood glucose level for gymnastics competition.

Respiratory exchange ratios were reported in only one field experience reviewed. Kreider et al. (Kreider et al., 1995) found no significant differences between groups, despite the fact that the carbohydrate trial tended to have greater values. This was similar to the present study in which the mean post-competition respiratory exchange ratio was found to be greater for the carbohydrate trial, but not significantly different than the placebo (~0.81 and 0.75 respectively). Therefore, carbohydrate supplementation did not seem to improve carbohydrate oxidation in field hockey or gymnastics competition. Although different from the original hypothesis, the respiratory exchange ratio results agree with the blood glucose data from this study. Since both groups finished the competition with similar blood glucose concentrations, it is only logical that they would also be oxidizing a similar amount of carbohydrate for fuel.

The mean resting (~0.26 l \cdot min^{-1}) and recovery (~0.32 l \cdot min^{-1}) oxygen consumption values reported in this study cannot be compared to previous investigations of female gymnasts as this data has not been recorded. The mean resting value is approximately 0.05 l \cdot min^{-1} greater than that predicted for an individual with a body mass of 60 kg (0.21 l \cdot min^{-1}). Although maximum oxygen consumption was not collected in this study, Montgomery and Beaudin (Montgomery & Beaudin, 1982) reported a mean value of 1.8 l \cdot min^{-1} for gymnasts aged 11-13 years of age and Noble (Noble, 1975) reported a mean value of approximately 2.8 l \cdot min^{-1} for gymnasts ages 18 to 22 years. The higher values reported by Noble likely reflect a higher training status and level of competition for his subjects.

This study failed to result in significantly different performance scores for the carbohydrate and placebo group. Although the mean score reported on the uneven bars, balance beam and floor exercise was higher in the carbohydrate group, it cannot be said to be a direct result of the beverage. Recently, Batatinha et al., (Batatinha et al., 2013) did show a reduced number of balance beam falls in younger gymnastics with CHO supplementation. In the present study, balance beam performance was determined by the mean value of seven participants. The average score was almost 0.10 better in the carbohydrate (8.43 \pm 1.16) than placebo (8.34 \pm 0.78) trial. Also of interest is that the only score to remain the same, regardless of the treatment, was the vaulting table. This event, lasting only five seconds, would not be predicted to benefit from carbohydrate supplementation. The vault is fueled by the immediate energy system which, unlike the short-term energy system used for
the remaining three events, is not reliant on carbohydrate availability.

The ability to maintain performance during an intermittent high-intensity sport such as gymnastics is partly reliant on the availability of muscle glycogen. Liver glycogen, released to help maintain blood glucose, is also essential. Although the present investigation did not find carbohydrate ingestion to enhance performance during the simulated dual competition, the overall results could benefit the sport of women’s gymnastics for other competitions. These findings could have an impact on gymnastics competitions of longer duration, such as invitationals and post-season competitions. The findings also impact competitions that occur on two or more consecutive days, such as the National Collegiate Gymnastics Association Championships.

It is unknown how long liver glycogen will continue to fuel gymnastics activity. Since glycogenolysis will only supply glucose for a certain length of time, this could negatively affect gymnastics performance in competitions of longer duration. The effect of a competition lasting longer than three and one-half hours on blood glucose concentration cannot be speculated based on the findings of the present study. In addition, utilizing greater liver and possibly muscle glycogen will decrease the amount of glycogen stored in these areas. The inability to fully resynthesize muscle glycogen could negatively affect performance occurring on the following day. It has been observed that eccentric exercise that results in muscle damage or soreness, typical of the sport of gymnastics, reduces or even prevents muscle glycogen resynthesis (Costill & Hargreaves, 1992). This enhances the potential benefit of carbohydrate supplementation during competitions that involve more than one day of performance.

Limitations of the Research

In attempting to establish a benefit from carbohydrate ingestion during gymnastics competition, several areas of concern regarding the experimental design emerged. The complexity of the gymnastics competition imposed restraints on data collection that were not fully anticipated beforehand. Difficulty existed in the timing of blood glucose measurement during the competition. Although a recovery time of two minutes was designated between completion of competitive routine and blood glucose analysis, subjects did not always report to the blood glucose testing station on time. The majority of blood glucose testing was conducted between four and six minutes of recovery from the routine. It appeared that blood glucose concentration escalated with greater recovery time. In addition to this, beverage consumption appeared to distract the subjects from the flow of the competition. According to an internal survey of the athletes, 35% felt that too much liquid was consumed at each interval, and 46% felt that the intervals were too close. Complaints regarding the frequency of urination were prominent.
**Implications for Future Research**

The present study attempted to link carbohydrate ingestion with blood glucose maintenance and enhanced gymnastics performance. The study collected data on blood glucose concentration during a gymnastics competition that, to our knowledge, has never been done before. The present study establishes a base of information that can be used for comparison in future studies. In attempting to establish a benefit from carbohydrate ingestion during gymnastics competition, the following two important implications emerged: 1) to establish optimal nutrition standards before, during and after gymnastics competition and 2) to utilize instrumentation that allows for the assessment of rate of blood glucose appearance and disappearance, levels of catecholamines and glycogen utilization.

The premise that performance can be improved through nutrition is one that is gaining much attention in the literature. Optimal nutrition and individualized nutrition is the current label given to the desire to consume exactly the right nutrients to allow for performance improvements and quick recovery. Manore, Barr and Butterfield (Manore, Barr, & Butterfield, 2000) summarized the position of the Dietitians of Canada, the American Dietetic Association and the American College of Sports Medicine. They stated that periods of intense physical activity require adequate carbohydrate and protein intake to replenish glycogen stores and repair damaged tissues. They added that the ingestion of a carbohydrate during activity fuels muscles, maintains blood glucose levels and decreases the risks of both dehydration and hyponatremia. Although general guidelines have been established by these groups, much more needs to be done in the area of specific sports, including gymnastics research, to take into account the specific demands of the sport and the individual differences of the participants.

**References**


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