Towards Optimizing the Timing of the Pre-Exercise Meal

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The purpose of this study was to compare the effect of a 6-hr versus 3-hr prefeeding regimen on exercise performance. The subjects were 8 active women (21.4 ± 0.9 years, 60.4 ± 2.4 kg, 19.9 ± 1.3% body fat, and 165.6 ± 2.1 cm). All women completed 2 exercise trials (separated by 3–6 d) on a treadmill where they ran at moderate intensity for 30 min with 30-s sprints at 5-min intervals, followed directly by increasing incrementally the grade until volitional fatigue was achieved. The exercise trials were performed 3 hr and 6 hr after consuming 40 ± 3 kJ/kg meal. Time to exhaustion was 0.75 min shorter (p = .0001) for the 6-H trials compared to the 3-H trials. There were no significant differences in submaximal or peak oxygen uptake, heart rate, or rating of perceived exertion (p > .05). The 6-H trials compared to the 3-H trials resulted in .05 lower RERs (p = .0002), and a 2 mmol lower blood lactate at exhaustion (p = .012). Blood glucose levels and cortisol responses to exercise were similar between trials (p > .05). However, both resting and post exercise insulin levels were lower during 6-H trials. It was concluded that performance of moderate- to high-intensity exercise lasting 35–40 min is improved by consuming a moderately-high carbohydrate, low fat, low protein meal 3-hr before exercise compared to a similar meal consumed 6 hr prior to exercise. Thus, athletes should not skip meals before competition or training sessions.

Key Words: glucose, insulin, cortisol, lactate, metabolic rate

The purpose of the pre-event (pre-competition) meal is to optimize glycogen stores, provide adequate hydration, while minimizing digestion and hunger during competition (1). No single meal appears best; however, there appears to be four important considerations in planning the pre-event meal: (a) timing, (b) amount, (c) nutrient content, and (d) fluids. While research has clarified the optimal nutrient content and amount (6, 9, 16, 22), as well as the importance of fluids (20), the timing of the meal is still somewhat controversial. Rose and Fuenning (19) have shown that pre-event emotions can slow digestion. Thus, to insure there is minimal digestion during exercise, the final meal might best be consumed 5–6 hr prior to competition. However, there appears to be substantial evidence that the final meal could be consumed 3–4 hr prior to exercise (21, 28). Thus, there is need to further examine and clarify the issue of optimal timing of the pre-event meal.

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In addition, many athletes train in the afternoon and, due to schedules, some may skip a midday meal before practice. Skipping a midday meal could result in what might be considered a 6-hr fast. Montain et al. (14) found that a 6-hr fast alters blood glucose utilization and resulted in similar carbohydrate utilization during exercise as an overnight or 12-hr fast. Therefore, athletes who skip the midday meal, resulting in a 6-hr fast, could be at a less than optimal status when they exercise. Therefore, the purpose of this research is to compare the effect on exercise performance when meal consumption occurs 6-hr prior to exercise with a 3-hr prefeeding regimen. Since the majority of studies on pre-event feeding have been done on males, this study utilized only female subjects.

**Methods**

**Subjects**

Eight women, ranging in age from 18–30 years, participated in this study. They averaged ($\pm SE$) 21.4 ± 0.9 years of age, 60.4 ± 2.4 kg of weight, 165.6 ± 2.1 cm of height, and had 19.9 ± 1.3% body fat. Self-reports indicated that all of the women were training for collegiate teams or triathlons. They exercised at least 5 days a week and had been training for a minimum of 3 months. All subjects were in good health with no physical limitations. Before participation, all subjects read and signed a consent form to act as a human subject previously approved by the Institutional Review Board at UNC-Chapel Hill. Both trials for each woman was completed during the same phase of her menstrual cycle (2, 11), which was confirmed by questionnaire.

**Instrumentation**

Exercise was completed on a treadmill (Q65, Quinton Instrument, Seattle, WA). Oxygen uptake ($\dot{V}O_2$) was measured using open circuit spirometry. The subjects breathed through a Hans Rudolph 2-way valve, which was connected on the inspired side to a gasometer (Rayfield Equipment, Waitsfield, VT) and on the expired side to a 5-L mixing chamber. The fraction of expired carbon dioxide and oxygen in the mixing chamber were analyzed using a SensorMedics LB-2 carbon dioxide analyzer (SensorMedics, Anaheim, CA) and an Applied Electrochemistry S-3A oxygen analyzer oxygen analyzer (Ametek, Pittsburgh, PA). The analyzers were calibrated before each trial using certified standard gases. A central processing unit ($\dot{V}O_2$ PLUS, J. Healy, North Reading, MA) received information from both analyzers, and computed $\dot{V}O_2$ and respiratory exchange ratio. Heart rates were continuously monitored on an oscilloscope and recorded the last 10 s of each minute of exercise using a three-channel electrocardiograph (Nihon Kohden, Orlando, FL).

Height, weight, and skinfolds were obtained for descriptive purposes. Height was measured using a stadiometer (Perspective Enterprises, Portage, MI, USA). Weight was determined using a Howe spring balance scale (Rutland, VT). Height and weight were obtained with the subject wearing shorts, a T-shirt and no shoes. To estimate body density, skinfold measurements were taken using Lange calipers (Cambridge Scientific, Cambridge, MD). The sites were the triceps, suprailiac, and mid-thigh (8). Percent fat was then estimated from the equation of Siri (23).
Five milliliter samples of blood were obtained before and immediately after (within 1 min) exercise from an antecubital vein utilizing EDTA treated vacutainer tubes. The blood was centrifuged for 15 min at 4 °C at 3000 rpms, the plasma removed and frozen at −50 °C for later analysis. Plasma was analyzed in duplicate for glucose using the glucose oxidase technique (Kit#510, Sigma Chemical, St. Louis, MO). Blood lactate was analyzed in duplicate using an Ektachem DT 60 Analyzer (Johnson & Johnson Diagnostics, Rochester, NY). Plasma insulin and cortisol concentrations were measured using radioenzymatic techniques (Diagnostics Products, Los Angeles, CA). The between samples C.V. for cortisol was 4%, while the CV for insulin was <3%.

Diets

The diets for all subjects was not controlled for the 2 days preceding testing; however, when questioned, all subjects indicated that they ate their normal three meals each day prior to testing; none fasted nor over-indulged. Each individual chose a breakfast from a list of choices and amounts provided by the investigators. The composition was derived as much as possible from the subjects’ normal diet. Food choices included cold cereals, pancakes and syrup, bagels, breakfast (English) muffins, low-fat muffins, toast, jam or jelly, milk, yogurt, fruits, and fruit juices. The breakfasts were eaten by the subject at home, and their contents and amounts were verified by the primary investigator via interview. The average energy content of the breakfast was ~40 ± 3 kJ/kg and consisted of approximately 55% carbohydrate, 25% fat, and 20% protein. The same breakfast was consumed before both trials. The lunch had an energy content of ~41 ± 3 kJ/kg of body weight, with a composition of approximately 60% carbohydrate, 20% fat, and 20% protein. The lunch corresponded as much as possible to the subject’s normal diet, as indicated on their food preference form. Foods included, turkey on whole wheat sandwich with low-fat mayonnaise, low-fat ham on whole grain bagel sandwich with mustard, salads with low fat dressings, fruit, cold cereal, vegetable soup, low-fat yogurts, skim milk, water, artificially sweetened ice tea, and pretzels. The energy and macronutrient content of all foods were determined using the Nutritionist IV analysis system (N2 Computing, San Bruno, CA). Finally, all the women indicated that they ingested water freely during the day of testing.

Procedures

Each subject completed one pretrial session and two experimental trials. At the pretrial session, the subjects signed the consent form and were medically screened for any possible contraindications to exercise. Height, weight, and skinfold were then measured. In addition, food preferences were determined using food preference questionnaire.

Once the subject finished the screening, she then completed a progressive exercise test to determine the proper speed to be used for the exercise trials. Electrocardiogram leads were attached, and she began walking on the treadmill. The treadmill speed was increased by 0.5 mph (0.8 kph) every 3 min until the subject reached heart rate of 150 beats per minute. The speed at the 150 bpm heart rate was recorded and used for the submaximal portions of the two exercise trials.
Each subject completed two exercise trials within 7 days: one trial 6 hr after consuming breakfast (6-H), and the other trial 3 hr after consuming breakfast and lunch (3-H). The order of trials was counterbalanced. All exercise testing was completed between 1,500 and 1,800 hr in order to simulate time of a normal afternoon training session. No physical training sessions were allowed for 48 hr prior to testing, while physical activity within 24 hr of testing was limited to walking or biking that was necessary for daily activity (to and from classes or home). Since the women indicated that they ingested water freely during the day of testing, and since resting hematocrits prior to each trial were similar (6-H = 36.7 ± 0.5%; 3-H = 36.0 ± 0.6%; p = .21), hydration status was believed to be similar before both trials.

For both trials, the women consumed breakfast. For the 6-H trial, the women reported to the lab for testing 6-hr after consuming only the breakfast. All subjects indicated they were compliant with the 6-hr fast. For the 3-H trial, the women ate their breakfast and then reported to the lab late morning to pick up their lunches. The pick-up procedure was used to accommodate the schedules of these college women. Each woman was instructed to eat the food at a specific time and to consume all the foods. However, if she was unable to eat all the food, she was told to bring her leavings back to the lab so that the total amount of food ingested could be determined. For reference, none of the subjects returned any food and when questioned, indicated that all food was eaten at the appropriate time. The women then reported to the lab 3-hr after consuming lunch to complete the exercise trial.

Both exercise trials followed the same procedures. ECG leads were attached, and the subject completed a 10-min seated rest. After 5 min of rest the subject began breathing through a mouthpiece. During the last 2 min of the rest period oxygen uptake (\(\dot{V}_O_2\)) and heart rate (HR) were measured. At the end of rest a blood sample was obtained, and the exercise bout was then initiated. The subject started with a 5-min warm-up at a comfortable walking speed. After the warm-up, the speed of the treadmill was adjusted to the previously obtained speed, which correlated to a heart rate of 150 bpm. This was the basic speed used throughout the exercise for both trials. Heart rate and RPE were obtained at 5-min intervals. \(\dot{V}_O_2\) and RER was recorded for one minute at 5-min intervals.

Following each of the first five data collection periods (min 6, 11, 16, 21, 26), the treadmill speed was increased by 2 mph for 30 s in order to induce a short period of sprinting. The short sprints were introduced to vary the intensity of exercise to more closely approximate training or team sports and to increase the use of carbohydrate stores. At the end of the 30 min of exercise, the grade of the treadmill was increased by 2.5% every 2 min until volitional fatigue (i.e., the subject is unable to keep running at that grade and chooses to stop). \(\dot{V}_O_2\), RER, heart rate, and RPE were determined minute-by-minute during the incremental stages. A blood sample was drawn within 1 min of the end of the exercise session.

**Statistical Analysis**

Means and standard errors were determined for all measures. Time to exhaustion was compared between trials using a repeated measures t test. The 5-min measures of heart rate, RPE, RER, and \(\dot{V}_O_2\) were analyzed separately using repeated-measures two-way ANOVA comparing trials over time. Blood glucose, lactate, cortisol, and insulin were also analyzed separately using a 2 × 2 repeated measures two-way ANOVA comparing trials over time (pre-post). The .05 level of significance was a
Table 1  Mean (±SE) Exercising Heart Rate, Oxygen Uptake ($\dot{V}O_2$), and Rating of Perceived Exertion (RPE) Responses for Both the 6-H and 3-H Trials

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trial</th>
<th>Rest</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>Maximal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate* (b/min)</td>
<td>6-H</td>
<td>62 ± 3</td>
<td>150 ± 4</td>
<td>156 ± 5</td>
<td>160 ± 5</td>
<td>161 ± 5</td>
<td>166 ± 5</td>
<td>168 ± 6</td>
<td>191 ± 2</td>
</tr>
<tr>
<td></td>
<td>3-H</td>
<td>63 ± 4</td>
<td>147 ± 4</td>
<td>152 ± 5</td>
<td>156 ± 5</td>
<td>157 ± 5</td>
<td>159 ± 5</td>
<td>163 ± 5</td>
<td>192 ± 2</td>
</tr>
<tr>
<td>$\dot{V}O_2$ (ml/kg/min)</td>
<td>6-H</td>
<td>3.3 ± 0.2</td>
<td>31.7 ± 1.2</td>
<td>32.6 ± 1.5</td>
<td>32.2 ± 1.4</td>
<td>33.3 ± 1.3</td>
<td>32.7 ± 1.5</td>
<td>33.0 ± 1.6</td>
<td>46.6 ± 2.4</td>
</tr>
<tr>
<td></td>
<td>3-H</td>
<td>3.4 ± 0.3</td>
<td>32.4 ± 1.4</td>
<td>31.8 ± 1.4</td>
<td>32.5 ± 1.6</td>
<td>32.9 ± 1.6</td>
<td>32.5 ± 1.3</td>
<td>33.6 ± 1.2</td>
<td>47.0 ± 1.8</td>
</tr>
<tr>
<td>RPE (6–20 scale)</td>
<td>6-H</td>
<td>—</td>
<td>10.4 ± 0.7</td>
<td>11.0 ± 0.7</td>
<td>12.0 ± 0.6</td>
<td>12.5 ± 0.5</td>
<td>13.3 ± 0.5</td>
<td>14.1 ± 0.5</td>
<td>18.5 ± 0.6</td>
</tr>
<tr>
<td></td>
<td>3-H</td>
<td>—</td>
<td>10.4 ± 0.8</td>
<td>11.3 ± 0.7</td>
<td>12.0 ± 0.4</td>
<td>12.4 ± 0.5</td>
<td>12.9 ± 0.4</td>
<td>13.3 ± 0.5</td>
<td>18.4 ± 0.5</td>
</tr>
</tbody>
</table>

*p < .05 for the 6-H vs. 3-H trials, min 5–30.
priori set for all analyses. A Tukey post hoc test was performed when the ANOVA resulted in a significant $F$ value.

**Results**

The subjects performed the 30-min of submaximal exercise for both trials at approximately $73 \pm 4\%$ of their peak oxygen uptakes (Table 1). There was no significant differences between trials in the submaximal $\dot{V}O_2$. In addition, the peak $\dot{V}O_2$ attained during the incremental exercise to fatigue was similar between both trials ($p > .932$). There were no significant differences between the 6-H and 3-H trials for peak heart rates ($p = .208$); however, submaximal heart rates were lower during the 3-H trials compared to the 6-H trials ($p = .046$). While the RPE was not significant between the two conditions (.428), there was a trend for a trials-by-time interaction ($p = .069$), as all 8 women reported higher RPEs for the final 10 min of submaximal exercise during the 6-H trial as compared to the 3-H trial. There was a significant difference in respiratory exchange ratio (RER) between the two conditions (Figure 1), with the RERs being approximately .05 units higher in the 3-H trial compared to the 6-H trial ($p = .0002$). Although the oxygen uptake responses were similar, the women performed significantly longer at a high intensity for the 3-H trial than they did for the 6-H trial (7.06 ± .89 min vs. 6.31 ± .85 min; $p = .0001$).

There was no significant difference in blood glucose between conditions (see Figure 2). Resting glucose was 4.66 ± .22 mmol/L for the 6-H trial and 4.83 ± .28 mmol/L for the 3-H trial. Mean post-exercise blood glucose levels were increased; 6-H = 7.16 ± .22 mmol/L; 3-H = 6.22 ± .22 mmol/L ($p = .061$). Figure 2 also shows that blood lactate levels were similar at rest but significantly higher at the end of exercise following the 3-H trial than the 6-H trial (9.7 ± .8 vs. 11.7 ± .4 mmol/L, respectively; $p = .012$).

![Figure 1 — Mean (+ SEM) respiratory exchange ratios at rest and during exercise comparing the 6-H and 3-H prefeeding regimens ($p = .0002$, 6-H vs. 3-H trials).](image-url)
Figure 2 — Mean (± SEM) resting and post exercise blood glucose and lactate concentrations comparing the 6-H and 3-H prefeeding regimens (Glucose: $p = .06$ post exercise 6-H vs. 3-H; Lactate: $p = .012$ post exercise 6-H vs. 3-H).

Plasma cortisol and insulin responses during the two trials are presented in Figure 3. Cortisol concentrations were not significantly different at rest between the 6-H or 3-H trials ($p = .477$). Although cortisol levels were slightly higher post exercise, the differences between trials was not significant ($p = .454$). The pre-exercise levels of insulin were lower before the 6-H trials compared to the 3-H trial ($p = .009$). Insulin concentrations were decreased with exercise for both trials ($p = .006$); however, the change in insulin (post-pre) was greater during the 3-H trials ($p = .028$).
Figure 3 — Mean (± SEM) resting and post exercise blood cortisol and insulin concentrations comparing the 6-H and 3-H prefeeding regimens (Cortisol: $p = .477$ 6-H vs. 3-H; Insulin: $p = .028$ 6-H vs. 3-H).

**Discussion**

The results of this research indicated that exercisers do not perform as well when they utilize a 6-hr prefeeding regimen as they do when the use a 3-hr regimen. The effect is evident during exercise that lasts as little as 38 min. Although the differences in total time between trials appears small, approximately 2%, if one examines only the high-intensity performance portion of the trial, omitting the first 30 min submaximal exercise, an 11% reduction in performance is evident. An 11% reduction in performance could be critical during competition. Thus, pre-event feeding using a moderate sized meal appears to be better accomplished by eating 3 hr before the exercise, especially when the exercise is of moderate duration and high intensity.
Although numerous researchers have noted that 12-16-hr fasts are detrimental to exercise performance (4, 13, 17, 25-27), the present study is the first to show a negative impact on exercise performance with as little as 6-hr of fasting. Since it appears that a 6-hr prefeeding regimen is detrimental, the question then becomes why this occurs. The answer is not clear from our results. One possible mechanism is muscle glycogen stores. Although muscle glycogen was not measured in this study, a 6-hr fast and only 38 min of exercise would not be expected to significantly deplete glycogen stores. While muscle glycogen depletion probably did not occur in this study, lower muscle glycogen stores at the onset of exercise in the 6-H trials may have contributed to the ~13% greater fat use was evident during this trial compared to the 3-H trials (3).

We noted that exercise elevated, rather than lowered, blood glucose levels, especially during the 6-H trials. Our result are not without precedent (3, 4, 12). Since the subjects in the present study were utilizing more fats during the 6-H trial than during the 3-H trials, the elevated blood glucose levels suggest that the subjects were mobilizing blood glucose but were not utilizing it, glucose conservation. Our data suggests that the glucose conservation was not related to cortisol, since our exercise did not induce any significant increase. The suggestion has been that any increase in, or maintenance of, glucose during exercise is a result of sympathetic nervous system (SNS) stimulation, catecholamines, or glucagon release, which would increase FFA availability and increased liver glycogenolysis (5, 12, 17). These actions are especially potent when combined with the decrease in insulin, which occurred more so during the 6-H exercise trials. Finally, there is evidence that suggests that the simple presence of the increased FFA in the blood results in a blockage of glucose uptake by the cell (29, 30). For whatever reason, a reduction in peripheral glucose uptake may have limited this source of fuel for high intensity exercise and contributed to fatigue, which promoted the decreased performance during high intensity exercise (15).

The RER during the 6-H trials was always approximately .05 units lower then during the 3-H trials. During the 3-H trials 67.5% of the energy came from carbohydrates, while only 32.5% was derived from fat. During the 6-H trials carbohydrates were still the primary source of energy (54-57%); however, there was greater fat utilization. The greater fat use during the 6-H trials could have been related to (a) lower insulin levels, (b) lower lactate levels, (c) increased lipolytic response to epinephrine, or (d) glycolytic flux (10, 30). However, a specific mechanism cannot be inferred from our results. Although the 6-H trials resulted in a shift toward greater fat utilization, the actual fat use over the duration of the trial was ~5-6 g greater for the 6-H versus the 3-H trials. This difference may not be truly physiologically significant.

Six hours of fasting resulted in lower resting plasma concentrations of insulin. This response was expected (12). In addition, the insulin response to exercise was also attenuated by 25% during the 6-H trials. However, the insulin response was reduced by 82% during the 3-H trials. The greater attenuation of insulin during the 3-H trials may simply be a result of the higher resting levels, which allowed them to drop further with the same exercise stimuli. Although these reductions were somewhat larger than previously reported (4, 12), they do suggest the effect of even short-term fasts on resting circulating insulin and insulin responses to exercise.

The 3-H trials resulted in higher levels of lactic acid at the end of exercise than the 6-H trials. This finding seems logical, since carbohydrate metabolism was greater and the high-intensity exercise duration was longer in the 3-H trials. Alternatively,
the difference in lactate levels may be related to a short-term fasting causing a change in substrate utilization. We found greater usage of fats for energy during the 6-H trials, compared to the 3-H trials, even at maximal intensity. The greater use of fats may in some way reduce lactate production (18). These results agree with the work of other researchers who studied fasts of a longer duration (4, 7, 13, 14, 17).

In summary, consumption of a moderate-sized, moderately-high carbohydrate, low fat, and low protein meal 3 hr before exercise enhances performance of moderate- to high-intensity exercise lasting 35–40 min, compared to a similar meal consumed 6 hr prior to exercise bout. Compared to the 3-hr regimen, the 6-hr fast before exercise reduced time to exhaustion and caused a greater reliance on fats as a source of energy during exercise. The results of this study have two implications for competitive athletes. One implication is that a 6-hr pre-event feeding regimen appears to be too long and can have a negative impact on exercise performance. The second implication is that athletes in training should not skip meals before training.

References


