Nutrient Timing: Affect on Exercise Performance, Training Adaptation and Body Composition

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INTRODUCTION
An important determinant of the adaptive response to exercise is the nutritional status of the individual.

While proper nutrition is certainly important in achieving exercise goals, it has become increasingly evident that when one eats can be just as important as what one eats.

That is, the timing of nutrient intervention or “nutrient timing” can have a significant impact on exercise performance, recovery and training adaptation.

In this presentation, the science behind nutrient timing will be discussed as it relates to exercise performance, recovery and training adaptation.

NUTRIENT TIMING
Simply stated, nutrient timing is the delivery of appropriate macronutrients during the time in which the body is primed to use them most effectively.

Nutrient timing as it relates to exercise can be divided into three phases:
- energy phase
- anabolic phase
- adaptation phase

ENERGY PHASE
The energy phase represents the period immediately prior to and during exercise. It can be divided into two periods:

- Pre-exercise period (the 4 hours before exercise)
- During exercise period
PRE-EXERCISE CARBOHYDRATE FEEDING: EFFECT ON ENDURANCE PERFORMANCE

Experimental Protocol X

N = 8, well-trained cyclists

Exercise: 80% VO$_2$max to exhaustion

Treatments: Provided 45 min before exercise
1. Water
2. 75 g glucose in solution

Pre-Exercise and Improvement


CAFFEINE AS A ERGOGENIC AID FOR AEROBIC ACTIVITY

Experimental Protocol

N = 9, well-trained cyclists
(2 females, 7 males)

Rode at 80% VO₂ max until exhaustion on two separate occasions

Treatments: Provided 60 min before exercise
Decaffeinated coffee (placebo)
Coffee with 330 mg

THE EFFECTIVE AMOUNT OF CAFFEINE

Experimental Protocol

N = 8, well-trained runners

Treatments: Placebo, 3 mg/kg body wt, 6 mg/kg body wt, and 9 mg/kg body wt
  Supplements were provided 1 hour before exercise

Exercise: Run to exhaustion at 85% VO$_2$max


Dietary Nitrate

**Functions of Nitric Oxide**

- Increase vasodilation and blood flow
- Lowers blood pressure and plasma triglycerides
- Increase muscle glucose uptake
- Enhances efficiency of oxidative phosphorylation
- Alter calcium release kinetics from the SR and reduces ATP turnover rate at actin-myosin crossbridges

**Nitric Oxide Production**

- Produced by the conversion of arginine to nitric oxide and citrulline by nitric oxide synthase
- In the body nitrate is converted to nitrite, which in turn is reduced to nitric oxide by deoxygenated hemoglobin, xanthine oxidase and other reducing enzymes.

**EXPERIMENTAL DESIGN**

- Randomized, double-blind, crossover experimental design
- N = 9 club competitive male cyclists
- Investigated the effects of beetroot juice on cycling time trial performance for 4.0 and 16.1 time trials.
- 500 ml of beetroot juice with or without nitrate provided 2.5 h before exercise
- Measure time to complete time trial, power and VO₂

CONCLUSION

- Pre-exercise supplementation with 100 g of CHO 30 to 60 min prior to exercise can help performance when supplementation cannot be done during competition.
- Caffeine in amounts of 3 to 6 mg/kg body wt 45 to 60 min prior to exercise can improve aerobic exercise performance.
- Natural products that are high in nitrate can be consumed and alter NO levels in the blood.
- Increasing nitric oxide availability can reduce the $O_2$ cost of exercise and improve endurance performance.

SUPPLEMENTATION DURING EXERCISE
Cycling at 70% VO$_{2\text{max}}$ to Exhaustion

Plasma Glucose (mM) vs. Exercise Time (hrs)

Experimental Protocol

Carbohydrate Supplementation During Variable Intensity Exercise

- Treatments were 10% CHO supplement and Placebo
- 9 male subjects
- Cycled for 30 min at 45% VO$_{2\text{max}}$, then alternated between 75 and 45% VO$_{2\text{max}}$ for 2.5 hours.
- After 3 hours of cycling, the subjects rode to exhaustion at 80% VO$_{2\text{max}}$
- Supplements (180 ml) were provided every 20 min over the first 3 hours of exercise
Effect of Carbohydrate/Protein Supplementation on Exercise Performance

Experimental Protocol

**Design:** Double blind, crossover

**Treatments:**
- CHO 7.3%
- CHO/PRO 7.3%/1.8%
  - 1.8 ml/kg ingested every 15 minutes during exercise and 10 ml/kg at the end of exercise

**Exercise:**
- 75% VO₂max until fatigue
- 15 hours later 85% VO₂max until fatigue

Saunders, M.J. et al. MSSE 2004
Low CHO/PRO Supplementation Increases Variable Intensity Exercise Performance

- \( N = 15 \)
- Randomized double blind repeated measures design
- **TREATMENTS**
  - CHO (6.0%) and CHO (3.0%)/PRO (1.2%) provided as 200 ml/20 min
- **PERFORMANCE TEST**
  - Cycle for 3 hours alternating between 45 and 75% \( \text{VO}_2\)\text{max} and then cycled to fatigue at 80% \( \text{VO}_2\)\text{max}
CONCLUSION

• Periodic supplementation with CHO/electrolyte drinks every 15 to 20 min can improve aerobic exercise performance.
• Using a combination of simple CHO will increase the rate of CHO assimilation, spare endogenous CHO stores and improve aerobic exercise performance
• The addition of protein to a CHO/electrolyte sports drink can limit the need for CHO while also improving aerobic endurance

ANABOLIC PHASE

The anabolic phase represents the immediate post exercise recovery period. Post exercise the body is highly responsive to nutrient intervention. Consuming the appropriate types and amounts of nutrients immediately to 45 minutes after an acute bout of exercise can:
  - increase rate of rehydration
  - increase the rate of muscle glycogen storage
  - reduce muscle damage
  - increase protein accretion
  - increase training adaptation

NUTRITIONAL SUPPLEMENTATION FOR POST EXERCISE RECOVERY
RETENTION OF FLUID REPLACEMENT

- Exercised subjects in heat until 1.8 L of fluid loss
- 30 min recovery passive recovery
- Replaced 0.9 L of fluid with water or an electrolyte solution
- 45 minutes later replaced final 0.9 L of fluid
- Followed fluid recovery for 2 hours


EFFECT OF A CARBOHYDRATE/PROTEIN SUPPLEMENT ON REHYDRATION

Fate of the Ingested Volume (n=19)

<table>
<thead>
<tr>
<th>Solutions</th>
<th>Fluid weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>0.5 ± 0.0</td>
</tr>
<tr>
<td>CE</td>
<td>0.5 ± 0.0</td>
</tr>
</tbody>
</table>

Other Fluid and Carbon Losses
Urine Losses
Volume Retained

EFFECT OF A CARBOHYDRATE/PROTEIN SUPPLEMENT ON REHYDRATION

Experimental Design

Subjects exercised to dehydrate by 2.5% of body weight. Immediately after exercise subjects consumed one of three liquid supplements equivalent to weight loss:
1. Carbohydrate/protein 6g CHO, 1.75g PRO, 45.8 mg Na
2. Carbohydrate 6g CHO, 45.8 mg Na
3. Water

Monitored recover for 3 hours


**Timing of Supplementation for Rapid Glycogen Synthesis**

1.5g CHO • kg⁻¹
Immediately Post Exercise

2 Hours Post Exercise

Glycogen Storage Post Feeding
(µmol • g⁻¹ wet wt • 2h⁻¹)

* Basal Immediately 2 h Later
Net Leg Glucose Uptake
(µg • min⁻¹ • 100cc⁻¹)

Amount of Carbohydrate Supplementation

GLYCOGEN SYNTHESIS
(µmol/g/h) during 4h of recovery

CHO SUPPLEMENT
g/kg body wt
Provided immediately after and 2h after exercise
Increases Glycogen Storage with Added Protein

Training Adaptation Effects of CHO/PRO Supplementation Post Exercise: Timing
**Maximal Oxygen Consumption**

- **% increase, absolute:**
  - All: 8.3%
  - CM: 12.5%
  - CHO: 6.5%
  - PLA: 6.0%

- **% increase, relative:**
  - All: 9.1%
  - CM: 14.3%
  - CHO: 6.4%
  - PLA: 6.5%

**Muscle Oxidative Capacity**

- **Succinate Dehydrogenase**
  - Baseline: CM, CHO, PLA
  - End: CM, CHO, PLA

- **Citrate Synthase**
  - Baseline: CM, CHO, PLA
  - End: CM, CHO, PLA

**Body Composition Changes**

- + 1121 g lean mass - (- 1135 g fat mass) = 2256 g

**Resistance Training Effect of Carbohydrate/Protein Supplementation**

32 subjects trained for 12 weeks while consuming several different nutritional interventions. Supplements consumed during exercise:
- 6% CHO solution
- 6 g EAA
- CHO + EAA

Carbohydrate Amino Acid Supplementation

32 subjects trained for 12 weeks while consuming several different nutritional interventions. Supplements consumed during exercise:
- 6% CHO solution
- 6 g EAA
- CHO + EAA

What is an optimal amount of protein in a single dose?
Protein Amount

- 20 g of protein (8.6 g of essential amino acids) maximally stimulates muscle protein synthesis after resistance exercise in young men.

Best Type of Protein to Use

Whey Protein Produces Best Response


mTOR Signaling Pathway

Preventing Protein Breakdown
CONCLUSION

- The addition of protein to a rehydration supplement will increase fluid retention and speed rehydration.
- The addition of protein to a CHO recovery supplement will increase the rate of muscle glycogen replenishment.
- A post exercise supplement combining CHO and protein will enhance protein synthesis post exercise and increase the rate of training adaptation.
- The addition of HMB could possibly reduce protein breakdown and increase rate of protein accretion.
ADAPTATION PHASE

The adaptation phase represents the 4 to 6 hours after the effects of the initial post-exercise supplement have dissipated. During this phase nutrient supplementation should be intermixed with regular daily meals and snacks.

<table>
<thead>
<tr>
<th>TIME (h)</th>
<th>Glycogen Concentration (mmol kg⁻¹ wet weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.40 g/kg</td>
</tr>
<tr>
<td>40</td>
<td>.35 g/kg</td>
</tr>
</tbody>
</table>

Muscle Protein Synthesis

- Rest
- 3H
- 24H
- 48H

High Protein Late Night Snack

Experimental Design

- Subjects (n=20 males) performed a combined endurance and resistance exercise protocol starting at 8:00 PM and lasting 2 hours
- Received a CHO/PRO (1:1 ratio) supplement or Water every 15 min during exercise and a supplement 15 min and 90 min post exercise
- Whole body and muscle protein synthesis was determined during exercise, and the subsequent 9 hours of recovery (7 hours of sleep)


Table 2: Whole-body and mixed muscle protein synthesis rates following W or C+P ingestion during and after resistance exercise in healthy young men

<table>
<thead>
<tr>
<th></th>
<th>W</th>
<th>C+P</th>
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<tbody>
<tr>
<td><strong>WB protein synthesis, μmol·kg⁻¹·h⁻¹</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>During exercise (2 h)</td>
<td>38.7 ± 1.5</td>
<td>49.9 ± 1.9*</td>
</tr>
<tr>
<td>During recovery (9 h)</td>
<td>28.6 ± 1.3</td>
<td>34.2 ± 1.4*</td>
</tr>
<tr>
<td>Total (11 h)</td>
<td>30.5 ± 1.3</td>
<td>37.1 ± 1.5*</td>
</tr>
<tr>
<td><strong>Mixed muscle FSR, %/h</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>During exercise (2 h)</td>
<td>0.056 ± 0.003</td>
<td>0.083 ± 0.011*</td>
</tr>
<tr>
<td>During recovery (9 h)</td>
<td>0.057 ± 0.004</td>
<td>0.056 ± 0.004*</td>
</tr>
<tr>
<td>Total (11 h)</td>
<td>0.057 ± 0.003</td>
<td>0.060 ± 0.008</td>
</tr>
</tbody>
</table>

Values are means ± SEM, n=10. *Different from W, P < 0.05.

Time

[Graph showing time points with different treatments: 3 mg %P Phenylalanine and 3 mg %C Tyrosine.]

Placebo

Protein

Whole-body protein kinetics 
μmol/phenylalanine

Breakdown Synthesis Oxidation Net Balance

Hes et al. MSSE (Published ahead of Print 2012)

Importance of Breakfast

Hes et al. MSSE (Published ahead of Print 2012)
Importance of Breakfast


“...This analysis provides evidence that skipping breakfast is not an effective way to manage weight. Eating cereal (ready-to-eat or cooked cereal) or quick breads for breakfast is associated with significantly lower body mass index compared to skipping breakfast”


“...Skipping breakfast is associated with increased prevalence of obesity”

Actions of Sustained Cortisol

- Cortisol actives LPL and increases fat storage
- Will lower growth hormone secretion
- Will inhibit the action of leptin lowering energy expenditure and increasing appetite
- Somatic consequences of sustained elevation of cortisol is excess deposit of fat in visceral adipose tissue and development of insulin resistance and hypertension

Meal Timing

- Intake in the morning is particularly satiating
- That it can reduce the total amount of energy ingested during the day
- Intake in the late night lacks satiating value
- Can result in overall greater daily intake

Experimental Design

- In this study 193 obese (BMI 32.2 ± 1.2kg/m²) sedentary non-diabetic adult men and women (47±7 y of age) were randomized to a low CHO breakfast (LC) or isocaloric diet with high CHO and protein breakfast (HCP).
- Fasting craving scores and breakfast meal challenge assessing hunger, satiety, insulin, ghrelin responses, where performed at baseline, after a diet intervention period (16 wk) and after a follow-up period (32 wk).
CONCLUSION

- A rapid rate of muscle glycogen and protein synthesis can be maintained by periodically supplementing post exercise
- The addition of about 40 g of a slow digesting protein prior to bedtime can stimulate muscle protein synthesis while sleeping
- Eating breakfast rapidly lowers cortisol levels that have been rising during the early morning hours and reduces the chances of overeating and gaining fat
<table>
<thead>
<tr>
<th>Time of day</th>
<th>Daily workout schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Workout</td>
<td>PM workout</td>
</tr>
<tr>
<td>7:00 AM</td>
<td>Breakfast</td>
</tr>
<tr>
<td>8:00 AM</td>
<td>Workout</td>
</tr>
<tr>
<td>10:00 AM</td>
<td>CP Suppl. (2:5:1)</td>
</tr>
<tr>
<td>11:00 AM</td>
<td></td>
</tr>
<tr>
<td>12:00 PM</td>
<td>Lunch (CP)</td>
</tr>
<tr>
<td>1:00 PM</td>
<td></td>
</tr>
<tr>
<td>2:00 PM</td>
<td></td>
</tr>
<tr>
<td>4:00 PM</td>
<td>CP snack (1:1)</td>
</tr>
<tr>
<td>5:00 PM</td>
<td>Workout</td>
</tr>
<tr>
<td>6:00 PM</td>
<td>Dinner (CP)</td>
</tr>
<tr>
<td>7:00 PM</td>
<td></td>
</tr>
<tr>
<td>8:00 PM</td>
<td></td>
</tr>
<tr>
<td>10:00 PM</td>
<td>CP snack (1:4)</td>
</tr>
</tbody>
</table>

Ratios listed are suggested carbohydrate-to-protein amounts in grams.

**SUMMARY**

- Supplementation prior to exercise with CHO, caffeine or foods high in nitrates can improve aerobic endurance
- Supplementation with CHO during exercise can improve aerobic endurance and this can be enhanced by using multiple simple carbohydrates and protein
- Supplementation soon after exercise with a CHO/PRO supplement can speed rehydration, glycogen replenishment, protein synthesis and training adaptation
- Supplementing with a small slowly digestible protein can increase protein synthesis during sleep
- Eating a wholesome breakfast will help control caloric consumption throughout the day and reduce the chances of weight gain