ENERGY DRINKS AND METABOLISM

The Effects of Caffeine and Energy Drinks on Skeletal Muscle Metabolism

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Drs Ross and Hudson (I am dedicating this talk to Bob’s memory)

Drs. Richter, Kiens, Dela, Kjaer

Marie-Soleil Beaudoin

Premila Sathasivam

Disclosures: none

OMAFRA Food Program
NSERC
NSERC Strategic
CIHR
Caffeine in energy drinks

Beginning in 2009, APNM has published 1 paper on EDs and 1 on Taurine.

I will address caffeine with exercise and then in resting conditions but will focus on muscle

Will end with a few comments for taurine and also Vitamin B3

Serving 50 -200 mg

Physical ‘energy’ (power or endurance); mental ‘energy’ (alertness, reactions, mental errors), increased fat metabolism; weight loss; appetite suppression;
Exercise

**The Human**

- **Brain**
  - Dependence
  - Fatigue/arousal
  - Motor recruitment
  - SNS - epinephrine
  - norepinephrine

- **Heart/Circulation**
  - HR
  - BP
  - TPR

- **Muscle**
  - Contractility
  - Fat oxidation
  - Glycogen use
  - Insulin resistance

- **Mouth**
  - MX absorption

- **Gut**
  - CHO absorption
  - incretins

- **Adipose**
  - FFA mobilization

- **Liver**
  - Glucose management
  - MX clearance

- **Kidney/ Sweat Glands**
  - Fluid loss

- **Adrenal**
  - Epinephrine
Effects of Caffeine on Endurance Times

- Graham & Spriet, 1991
- Cadarette et al, 1995
- Pasman et al, 1995
- Sasaki et al, 1987
- Cadarette et al, 1982
- Flinn et al, 1990
- Mohr et al, 1998
- Van Soeren et al, 1998
- Blood & McLellan, 2002
- Crocker et al, 1987
- Bell & McLellan, 2002
- Collopo et al, 1990
- Perkins & Williams, 1975
- Graham & Spriet, 1991
- Trice & Haymes, 1978
- Costill et al, 1978
- Butts & Crowell, 1985
- Cohen et al, 1996
- Greer et al, 2000
- Graham & Spriet, 1991
- Spriet et al, 1992
- Van Soeren et al, 1998
- Greer et al, 2000
- Graham et al, 1998
- Mohr et al, 1998
- Van Soeren et al, 1998
- Greer et al, 2000
- Graham & Spriet, 1991
- Spriet et al, 1992
- Van Soeren et al, 1998
Effects of Caffeine on Performance

- Decaf vs Coffee
- Plb vs Caf
- Plb vs Caf/Ele

Graph showing data points labeled with authors and years. For example:
- Kovacs et al, 1998
- Berglund & Hemmingsson, 1982
- Wemple et al, 1997
- Wiles et al, 1992
- MacIntosh & Wright, 1995
- Bruce et al, 2000
- Cohen et al, 1996

Collomp 1992: 1 sec
Sport drinks and Performance
Kovacs et al., JAP 82: 709-715, 1998

<table>
<thead>
<tr>
<th>Avg power (W)</th>
<th>W</th>
<th>CES</th>
<th>+150</th>
<th>+225</th>
<th>+320</th>
<th>mg/l</th>
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<td>295</td>
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<td>(10)</td>
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<tr>
<td>Caffeine dose (mg/kg)</td>
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<td>0</td>
<td>2.1</td>
<td>3.2</td>
<td>4.5</td>
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</table>

Caffeine dose can be quite low

Sport drinks, colas, EDs are effective

Ivy et al. 2009; RB 2.4 mg/kg; 64.5 min – 61.5 min

Coke; 1.9 mg/kg; 2.7% faster

if there is a dose response it is small
What do we see in the blood?

- Increased FFA, epinephrine and lactate
- Little to no change in glucose and insulin
- Does this reflect the metabolism of the active muscle?
Does Caffeine increase fat oxidation and spare glycogen?

- Direct Fick of leg plus biopsies
- **No difference in glycogen**
- **No difference in glucose uptake**
- **No difference in lactate release**
- **No difference in muscle lactate**
- **No difference in FFA uptake**
Caffeine, exercise and stable isotopes

- Raguso et al. Metab 45:1153-1160, 1996. Theo- no diff in RER or Ra or Rd for glycerol or FFA and no diff Ra for glucose but less Rd

- Roy et al Eur JAP 85:280-286, 2001. No diff RER; no diff in Ra or Rd for Glucose

- These are whole body measures

- How could caffeine result in fat/weight loss?
It is a rare study that reports a decrease in RER/RQ i.e. increase in fat oxidation

- Original support by Costill et al was convincing and based on RQ and muscle TG’s

- Close examination of the data (Graham CJAP 26:S103-119, 2001) shows that quantitatively the TG data can not be correct. It is difficult to measure IM TG and they are energy dense.
Tetraplegic patients

Electric stimulation of muscles

So overall, to the relief of football and hockey players, one does not need a brain!

No role of CNS
No change in epi
Metabolism not limiting
So????

So what is critical?

Muscle can work harder or longer- but no change in ‘maximum’ output (Note: training/health benefit)

Effect is seen in wide range of circumstances (sec to hours)

If there is ONE mechanism, then it must be a fundamental aspect

CHO/Fat metabolism do not appear to be altered

Blood flow not altered

CNS not essential

$Ca^{2+}$
At rest: Caffeine plus CHO results in high blood glucose. **WHY?**

**Glucose**

- Gut
- Liver
- Muscle
- Adipose

**Insulin**

- Liver
- Pancreatic β-cells

**C-peptide**

"insulin clamp" provide the insulin and glucose- measure how much glucose is ‘used’ for a given insulin

Oral glucose tolerance test: give set amount of glucose orally and measure blood glucose and insulin
Caffeine plus CHO results in high blood glucose. WHY?

The high glucose not due to low insulin!

The subjects are resistant to the insulin!

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Insulin Levels for an OGTT on Lean & Obese Subjects
Insulin Sensitivity Index* for Various Studies During Placebo and Caffeine Trials

Caffeine increases glucose AUC 14-25% and decreases ISI by same amount.

Caffeine increases insulin AUC 25-42%.


Caffeine decreased insulin-mediated but not exercise-mediated glucose uptake.

**Muscle is the major tissue storing CHO postprandially.**

Less glucose taken up for a given insulin and of this amount, less is stored, but oxidation is not effected!
Infusion Rates for Various Clamp Studies During Placebo and Caffeine Trials

PLACEBO (umol/kg/min)
0
20
40
60

CAFFEINE (umol/kg/min)
0
20
40
60

Unpublished post ex
De Galan et al (Control 5mM)
De Galan et al (Type 1 - 3.5mM)
De Galan et al (Type 1 - 2.5mM)
De Galan et al (Control 2.5mM)
Greer et al (5.2 mM)
Keijzers et al (5.0 mM)
Thong et al (5.2 mM)
Caffeine decreases GIR 13-24%
Subjects and conditions

- **CAFFEINE/COFFEE**
- Men/women; young/mature; lean/obese; type 2 diabetic
- Low and high GI cereal
- First and second meal
- With/without ingestion of fat
- Pregnant women – GDM
- Tetraplegics
B vitamins?

Most health benefits of vitamins etc. are for deficiencies and are found with systemic long term supplementation

B vitamins are water soluble – readily excreted

**B3/Niacin/nicotinic acid**: can inhibit adipose tissue mobilization of FFA

Therapeutic doses (100 mg- 1g/d) nicotinic acid, GPR109A receptor binding and cAMP/inhibition of lypolysis

**Typical serving 10-40 mg**

*Stellingwerff et al Am J Physiol Endocrinol Metab 284: E589–E596, 2003*

20 mg/kg bm (70 kg person = 1400 mg) one hour before exercise )~65% VO2max fasted [FFA] decreased from ~0.5 mM to ~0.2 mM

stayed very low during exercise (<0.1 mM); CHO oxidation increased 15%

**Terry speculation: no effects on muscle metabolism at this low dose**
Taurine?

Putative roles: osmotic reg; Ca$^{2+}$ handling; antioxidant; ....
Typical serving 10-2000 mg

studies: few; descriptive; performance and/or crude measures of short term oxidative stress

Does it get into circulation? Yes.
Where does it go?

Blood and muscle biopsy measures:
Muscle concentration: 40-50 mmol/kg dw (25-35% of TAA 170-180 mmol/kg dw)

plasma concentration: 10-40 umol/l (1-% of Total AA 1050 umol/l)

Femoral A-V: 1-2 umol/l (rest and exercise)

Terry speculation: no effects and/or very transient effects with muscle and some health claims would likely need chronic treatments
conclusions

• We know little about muscle metabolism and energy drinks
• Based on studies of each ingredient, EDs **likely increase** physical endurance
• EDs **likely do not** alter fat or CHO metabolism
• EDs **likely** result in periods of insulin resistance in muscle
GAPS/important questions:

1- what are the metabolic responses and what are the ‘active’ ingredients?

2- Who responds? Age, sex, medical conditions?

3- What are the acute vs chronic effects of these responses? Endurance/performance vs wt loss, insulin resistance

4- are any responses beneficial? (training)

5- are any responses negative? (insulin resistance)
• Whole Body and Tissue-Specific Effects of Energy Drinks on Metabolism: Beyond Skeletal Muscle

• Jane Shearer — University of Calgary