

Brain MRS after Consumption of Commercially Available Energy Drink

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Introduction: “Energy drinks” (EDs) are beverages that contain caffeine, taurine, vitamins, herbal supplements, and sugar or sweeteners and are marketed to improve energy, weight loss, stamina, athletic performance, and concentration(1). The popularity of energy drinks has grown exponentially with a 240% increase in sales from 2004-2009 (2). It has been reported that the highest consumers of EDs are males aged 18 to 34 years (3) but there is a reported increase in consumption during childhood (4,5). Concern from health authorities (6,7) and published studies (1,8,9) regarding the potential health implications associated with the consumption of EDs is rapidly increasing due to their increased availability and consumption. The aim of this study was to undertake *in-vivo* Magnetic Resonance Spectroscopy (MRS) to non-invasively study the effects of consuming a “formulated caffeinated beverage” (Red Bull™) on the human brain metabolite levels.

Methods: Nine healthy male volunteers (age range: 20-25 years) underwent one-dimensional (1D) MRS on a 1.5 T Achieva XR MR scanner (Phillips, The Netherlands) with supine and head-first positioning, and using a phased-array head coil. All subjects were fasted for 3-hrs prior to examination, and refrained from consuming caffeinated products for the 24hrs prior to MRS examination. Five control subjects (n=5) were placed in the scanner and a spectrum was acquired every 5 minutes for 45 minutes. Four other subjects (n=4) were scanned before (once) and after (every 5 min for 45 minutes) consuming two standard 250mL cans of Red Bull™. The standard nutritional profile per serve (250ml) contains 1000mg of taurine, 80mg caffeine, 60mg of glucuronolactone, 50mg inositol, 20mg niacinamide, sugars and vitamins in minor concentrations. While no guidelines exist for the safe consumption of energy drinks, it is recommended by the manufacturers of Red Bull not to consume more than two standard 250mL cans per days. In all cases, MR spectra were acquired with a point-resolved spectroscopy (PRESS) sequence (10): TR 1.5 s, TE 35 ms, acquired vector size 1024 points, number of averages 192, voxel dimensions (size) 26x15.4x18 mm³ (7.2 cm³), spectral width 1kHz, water suppression enabled, acquisition time 5 min. The spectroscopic voxel was chosen following 3-plane orthogonal imaging scan and was positioned in bi-occipital lobe as shown in Figure 1. The study had local Institutional Review Board (IRB) approval. Additionally, a spectrum from Red-Bull™ drink was acquired using identical settings as above.

MRS Data Analysis and Statistics: All spectra were Fourier transformed, baseline- and phase-corrected. Eddy current correction and water scaling options were both enabled in LCModel (11). A GAMMA simulated spectral basis set at TE of 35ms and 1.5 tesla was used to analyse spectra. Metabolite ratios to total creatine (t-Cr: creatine and phosphocreatine), average, range, along with their respective standard deviation (SD) and standard error (SD/sqrt(n)) were calculated for all metabolites and those with Cramer-Rao lower bounds (CRLB) less than 20% were used for comparison. Spectral quality was good at all times.

Results and Discussion: Concentration ratios of phosphocreatine (PCr), glycerophosphorylcholine (GPC), glutathione (GSH), inositol (Ins), total N-acetylaspartate and N-acetylaspartylglutamate (NAA+NAAG, t-NAA), glutamate and glutamine (Glx), and macromolecules (proteins) MM09, MM20 to t-Cr were calculated. Average absolute concentration (institutional units) of t-Cr was also calculated and was found to be the same for both groups. Results are shown in Figure 2. PCr, Ins, and MM20 ratios decreased while GSH and Glx ratios increased as a result of drinking. Strong resonances detected in the pure Red Bull spectrum matched with taurine (3.2, 3.4ppm), caffeine (3.4, 3.6, 4.0ppm) and inositol (3.3,3.6,4.0ppm). However, clear indication of the presence of taurine in the brain was not detected.

A previous study (12) reported a large spectral increase of taurine (3.35 ppm) in human cerebellum *in vivo* after 25 minutes after consuming **three** cans of Red Bull in 50% of their cohort (n=7). During the present study, the CRLB of taurine was higher than 20% and a reliable ratio to t-Cr was not calculated. It is expected that if taurine had been elevated in the brain as a result of Red Bull consumption, then it would have been detected by LCModel. Another possibility for not detecting taurine elevation in this study was due to the use of TE of 35 ms in the present study compared to 15 ms in (12), where a longer TE allows for a larger transverse relaxation effect and concomitant disappearance of fast relaxing species such as taurine. Also, Roser et al noted that cerebellum was more sensitive for detecting taurine elevation than bi-occipital grey matter.

Caffeine is known to effect neurotransmitter concentration in the brain and a higher average for Glx as a result of Red Bull consumption is thus not surprising. This finding is in agreement with results obtained by Wajda et al that significant increase in glutamine levels was found in caffeine-treated mice (13).

The decrease of macromolecules symbolised with MM20 (2.25, 2.0, 3.0 ppm) was surprising. This could be explained by the presence of Red Bull ingredients that co-resonates with MM20. Of course, these MM resonances are not related to myelin content, but rather to proteins and MM that are present in brain tissue (14). The majority of these resonances can be assigned to methyl and methylene resonances of protein amino acids, such as leucine, isoleucine, valine, methionine, threonine, alanine, lysine, arginine, glutamate and glutamine (15).

Conclusion: 1H 1D MRS was able to detect decrease in PCr, Ins, and MM20, and an increase in GSH and Glx for the first time as a result of consumption of energy drink that are high in caffeine, taurine, vitamins and other dietary supplements.

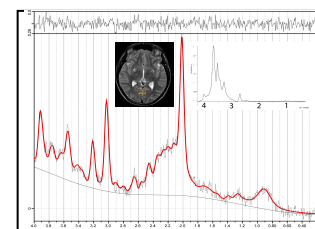


Figure 1. A typical localized 1H spectrum and its fitting (red trace) in LCModel. Voxel position is shown in brain image inset. Spectral inset shows a localized 1H spectrum of Red Bull drink acquired with similar parameters to *in vivo* spectra.

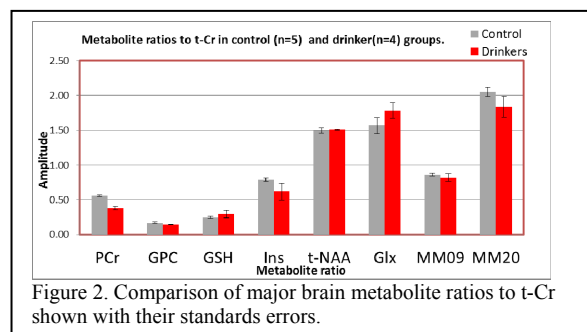


Figure 2. Comparison of major brain metabolite ratios to t-Cr shown with their standards errors.

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