

ORIGINAL RESEARCH

Effects of Sleep or Food Deprivation During Civilian Survival Training on Cognition, Blood Glucose and 3-OH-butyrate

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Objectives.—The study was designed to compare effects of food deprivation (FD) and sleep deprivation (SD) on cognition during survival training.

Methods.—In a cross-over design (n=12), the effects of FD (up to 66 hours followed by 500 kcal intake over 24 hours) and SD (up to 50 hours) on cognitive variables, blood glucose, and 3-OH-butyrate were studied.

Results.—Food deprivation and SD impaired attention-dependent tasks. The FD impairment of simple reaction time was independent of blood glucose levels, which were normalized by a 500 kcal intake over 24 hours while the reaction time was not. Sleep deprivation and FD impaired maze-solving performance on all variables except rule breaks, which were significantly occurring after 50 hours of SD. Delayed word recall was impaired by SD for 50 hours. On the Balloon Analogue Risk Task, SD was associated with reduced risk-taking. In a gambling task, both SD for 50 hours and FD for 66 hours were associated with a tendency to make early choices when presented with consecutive choices, but the risk-taking was not affected.

Conclusions.—Sleep deprivation has multiple cognitive effects, including attention, memory, visual-spatial ability, and risk-taking. Food deprivation had no effect on risk-taking, while the other tasks were affected in a way similar to SD but were less pronounced. The FD effects on cognition did not appear to depend on blood sugar levels. The need to sleep should be prioritized in survival situations to avoid cognitive impairment.

Key words: cognition, sleep deprivation, food deprivation, emergency, survival, risk-taking behavior

Introduction

Recommendations concerning emergency or survival situations focus on unexpected, prolonged subsistence without access to resources commonly available in human urban or rural communities.^{1–3} The advice is based on a mixture of personal experience, military survival training, and archaeological and anthropological studies of hunter-gatherer and nomadic societies.

The basic needs relevant to civilian life that are taught in survival training courses are usually: 1) protection

from exposure; 2) water; and 3) food. Exposure to cold or heat may be fatal within a few hours, or even less, while dehydration due to lack of water takes several days to develop into a life-threatening level. Deaths from starvation are commonly reported after more than 6 weeks of total lack of food.^{4,5} In practice, it seems that deaths and serious injuries among subjects exposed to a survival situation often are the result of exposure or risky behavior.^{6,7} Therefore, factors contributing to poor judgment should be minimized.

The number of studies on the effects of sleep deprivation (SD) and food deprivation (FD) on decision-making is small. There are some studies that were carried out in a military training context that partly address the

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question.⁸⁻¹¹ However, data relevant to the civilian survival situation is lacking. Furthermore, while the combined effects of SD and FD and other stressors in a simulated combat situation are severe on cognitive function,^{8,9} it is not clear what the relative contributions may be from each factor.

There is vast literature on the effects of SD on cognitive functions as well as the risks involved in SD (see review by Harrison and Horne¹²). Less is known about cognitive effects of food deprivation. Attention deficits were found in children not eating breakfast,¹³ but no effect was found in a controlled caloric restriction study.¹⁴ However, the effects of hypoglycemia on cognition in diabetic and nondiabetic subjects have been extensively researched.

This study compares the effects of SD and FD on cognitive functioning with special reference to attention and risk-taking, both of which may be important in survival situations. Metabolic adaptation is monitored in parallel in order to facilitate interpretation of data. The aim of the present study was to directly compare the impact of SD with FD on selected cognitive functions. In order to investigate the effect of a specific recommendation,² the ability of a small amount of carbohydrates (500 kcal over 24 hours) to counteract the effects of food deprivation was also tested.

Materials and Methods

SUBJECTS

Five females and 7 males, 21 to 52 years old, non-smokers, weighing 50 to 87 kg, without diabetes or sleep disorders or any other disease considered likely to interfere with the experiment, participated in the experiment that was included as a major part of a 9-day course arranged by the Swedish Survival Guild and the Swedish Civilian Defence League. The subjects' active engagement in survival training ranged from 1–18 years. All subjects were right-handed, except one who was ambidextrous but uses the right hand to control the computer mouse. The study was approved by the Ethics Review Board at Karolinska Institute and the subjects were given oral and written information prior to giving their written informed consent to participate.

Subjects were randomized into 2 different cohorts, with 6 subjects per group, stratified for gender (2 females in one group and 3 in the other): 1) sleep deprivation first and food deprivation second ("group SF"); or 2) food deprivation first and sleep deprivation second ("group FS") (see Table). On every study day (except training day) the cognition test battery was administered between 8 AM and 12 AM and blood samples were collected prior

Table. Overview of activities related to the study protocol

DAY	ACTIVITIES FOR SF	ACTIVITIES FOR FS
1 Sat	Training on cognition test battery	Training on cognition test battery
2 Sun	Baseline measurements	Baseline measurements
3 Mon	First day of sleep deprivation	First day of food deprivation, last food prior evening at 16:00
4 Tue	Second day of sleep deprivation. Sleep allowed for 4 hours after testing and the following night.	Second day of food deprivation
5 Wed	First day of food deprivation, last food prior evening at 16:00	Third day of food deprivation
6 Thu	Second day of food deprivation	First day of food restriction to 500 kcal starting after testing previous day and last intake at 08:00
7 Fri	Third day of food deprivation	First day of sleep deprivation
8 Sat	First day of food restriction to 500 kcal starting after testing previous day and last intake at 08:00	Second day of sleep deprivation. Sleep allowed for 4 hours after testing and the following night.
9 Sun	Baseline measurements	Baseline measurements

to the testing. All urine was collected in 24-hour portions. Food intake was scheduled.

Body weight was measured at the same time each day after emptying the bladder and while wearing standardized clothing. Capillary glucose and ketones were analyzed on-site. Remaining clinical chemistry analyses will be discussed elsewhere.

COMPUTERIZED COGNITIVE MEASUREMENTS

For this study the computerized cognition test battery was programmed in Delphi (Embarcadero, San Francisco, CA) on a laptop PC by the first author. Simple reaction time, choice reaction time, digit span, and word recall are all based on tests discussed by Lezak et al¹⁵ and were modified to fit the setting used in this study. To avoid a learning effect as a confounding factor, the

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