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The effect of cafeteria diet from postweaning to adolescence on the cognitive performance of rats

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Abstract

Background: Overconsumption of high-calorie foods not only causes obesity and metabolic disorders but also affects some activities of the nervous system, such as cognitive processes. The present study aimed to investigate the effect of a cafeteria diet from post-weaning to adolescence on the cognitive performance of rats.

Methods: Pregnant Wistar rats were fed a normal diet and water from the day of delivery to 20 days postpartum. Male offspring were then assigned to one of 3 groups: a cafeteria diet (sausages, cakes, raisin cookies, carrots, white milk chocolate, and chocolate milk) (CAF), a cafeteria diet with simvastatin (CAF-S), or a control group (CTRL). After the treatments were completed, the cognitive performance of the rats was evaluated using the Morris water maze test.

Results: The CAF group showed reduced learning compared to the other two groups, and they took longer to find the hidden platform on all days of the experiment ($P \leqslant 0.001$). The CAF-S group, which received simvastatin at a dose of 50 mg/kg, had a significantly shorter time to find the hidden platform compared to the CAF group ($P \leqslant 0.05$). During the memory recall phase, after removing the platform, the CAF-S group spent less time in the target quadrant compared to the CTRL and CAF-S groups ($P \leqslant 0.05$).

Conclusion: The results indicated that the cafeteria diet decreased the rats' learning and long-term memory. This effect is likely due to the high-fat content in the cafeteria diet. However, simvastatin prevented this decrease in the rats fed a cafeteria diet. These findings suggest that interventions targeting the metabolic pathways affected by a cafeteria diet may have potential therapeutic benefits for cognitive disorders.

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Highlights

What is current knowledge?

Overconsumption of high-calorie foods causes obesity and metabolic disorders and disturbs some nervous system activities, including cognitive functions. However, the effect of its consumption during breastfeeding by the mother has not been investigated until adolescence.

What is new here?

1- A cafeteria diet reduces learning and long-term memory in mice.
2- Simvastatin reduces the effect of cognitive dysfunction caused by excessive consumption of cafeteria diet in rats.

Introduction

The consumption of high-calorie diets has become increasingly prevalent in modern societies, contributing to the global obesity epidemic (1,2). In addition to its effects on physical health, there is growing evidence that a high-calorie diet is also detrimental to cognitive function, including learning and memory (3,4). This is particularly true for diets that are high in fat and sugar, as these have been shown to impair cognitive performance in both human and animal studies (5,6).

One popular method for studying the effects of high-calorie diets on cognitive function is the Morris water maze test. This test involves placing rodents in a pool of water and training them to find a hidden platform using visual cues. The test is widely used to assess spatial learning and memory in rodents (7). Cafeteria diets, characterized by a range of highly palatable, energy-dense foods, have been shown to induce obesity and metabolic dysfunction in rodents (8,9) and have also been linked to cognitive deficits, including impaired learning and memory in the Morris water maze test (10,11). Despite the growing interest in the effects of cafeteria diets on cognitive function, there is still much to be learned about the specific mechanisms by which these diets impact the brain. One potential avenue for investigating these mechanisms is using pharmacological interventions that target the metabolic pathways implicated in the effects of high-calorie diets on cognitive function. One such intervention is simvastatin, a drug commonly administered to treat high cholesterol levels. Simvastatin has also been shown to have neuroprotective effects, including the ability to improve cognitive function in animal models of neurodegenerative diseases (12,13).

This study aimed to investigate the effect of a cafeteria diet from post-weaning to adolescence on the cognitive performance of rats using the Morris water maze test as a measure of spatial learning and memory. A particular focus was placed on the role of simvastatin in mitigating any cognitive deficits induced by the diet. By elucidating the cognitive effects of a cafeteria diet and the potential protective effects of simvastatin, this study may contribute to our understanding of the links between diet, metabolic health, and cognitive function.

Methods

Animals:

Male and female Sprague-Dawley rats (n=40) were obtained from a commercial breeder (Charles River Laboratories, Wilmington, MA, USA) at postnatal day 21. Rats were housed in a temperature-controlled room with a 12:12-h light-dark cycle and provided with ad libitum access to food and water throughout the study. Male offspring were assigned to 3 groups: control diet (CD), cafeteria diet (sausages, cakes, raisin cookies, carrots, white chocolate, and chocolate milk) (CAF), or cafeteria diet plus simvastatin (CAF+S). The cafeteria diet was composed of a range of highly palatable, energy-dense foods, such as cookies, cheese, and sweetened condensed milk, which were freely available to the rats for 8 weeks, starting on postnatal day 21. The control diet consisted of the standard laboratory chow (LabDiet 5001, Purina Mills, St. Louis, MO, USA). Simvastatin was administered orally at a dose of 50 mg/kg body weight (14) once daily for the entire duration of the study.

Morris Water Maze Test:

Spatial learning and memory were assessed using the Morris water maze test (7). The water maze consisted of a circular tank (diameter: 180 cm, height: 60 cm) filled with water (22°C) made opaque with nontoxic white paint. A hidden escape platform (10 cm in diameter) was submerged 1 cm below the surface of the water in a fixed position throughout the testing phase. The water maze was located in a dimly lit testing room with some extra-maze cues visible on the walls. Rats underwent 4 trials per day for 5 consecutive days. In each trial, the rats were placed in the water facing the wall of the tank at one of 4 starting positions (north, south, east, or west) in a pseudorandom order. The time taken to locate the hidden platform (escape latency) was recorded, and the rats were allowed to remain on the platform for 10 sec before being removed from the water. On the sixth day, a probe trial was conducted, in which the platform was removed, and the rats were

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allowed to swim freely for 60 sec. The time spent in the quadrant of the pool where the platform had been located during training (target quadrant) was measured.

Statistical analysis:

The data were analyzed using a two-way analysis of variance (ANOVA) with diet (CD or CAF) and simvastatin treatment (none or S) as the factors. Post-hoc comparisons were performed using Tukey's test. A P-value < 0.05 was considered statistically significant. All statistical analyses were performed in SPSS v. 25.0 (IBM Corp., Armonk, NY, USA).

Results

Evaluation of learning:

The results of the Morris water maze test revealed that all groups showed an improvement in spatial learning over the course of the experiment. As shown in Figure 1, the time taken to find the hidden platform decreased in all groups over time, indicating improved spatial learning abilities.

However, the group that received only the cafeteria diet exhibited impaired learning compared to both the control group and the cafeteria diet + simvastatin group. These rats took significantly longer to find the hidden platform on all days of the experiment (P≤0.001), indicating a reduction in their spatial learning abilities.

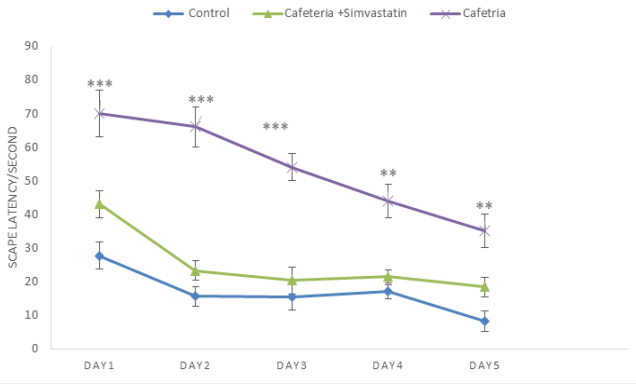

Figure 1. "Effect of Cafeteria Diet and Simvastatin Treatment on Spatial Memory Acquisition in the Morris Water Maze: Average Escape Latency Within Each Day (Comprising 5 Trials). Values are presented as mean ± standard error of the mean (SEM). n=6 in each group. Asterisks indicate a significant difference from the control group (*P < 0.05, **P < 0.01, ***P < 0.001)."

Swimming speed:

The swimming speed of the rats was also evaluated in different groups to account for any differences in movement performance that could affect the time taken to complete the maze. As shown in Figure 2, there was no significant difference in swimming speed between the different groups on any day of the experiment.

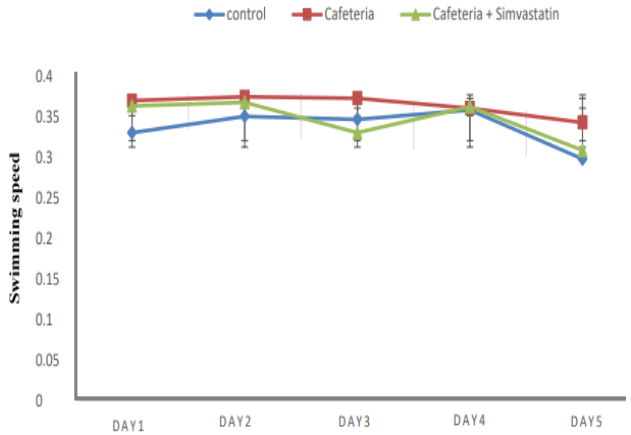

Figure 2. Comparison of swimming speed during training days. Values are Mean±SEM. n=6 in each group. There were no significant differences in swimming speed between different groups.

Memory evaluation:

After 5 days of training, on the sixth day (probe day), the platform was removed from the maze, and the time spent in the target quadrant was considered an indicator of memory retention. As shown in Figure 3, the cafeteria diet resulted in a significant decrease in the time spent in the target quadrant (P≤0.05), indicating impaired memory retention.

However, treatment with simvastatin at a dose of 50 mg resulted in improved memory retention, with a significant difference observed between the cafeteria diet group and the simvastatin-treated group (P≤0.05). Interestingly, there was no significant difference in memory retention between the simvastatin-treated group and the control group (P≤0.05).

Overall, these findings suggest that the cafeteria diet may impair both spatial learning and memory retention but that simvastatin treatment may improve both learning and memory function. The swimming speed of the rats did not appear to be a factor affecting maze completion times.

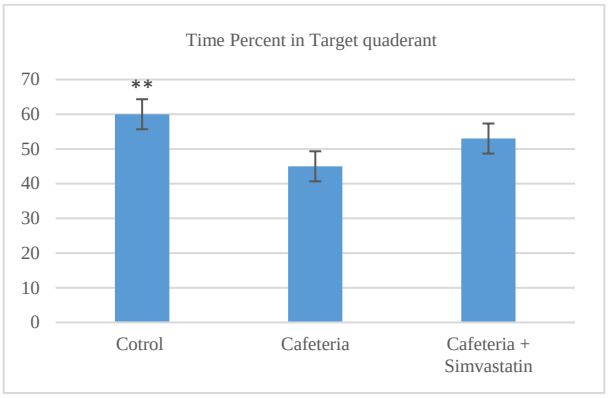

Figure 3. Water maze Mean (± standard error of the mean) percentage of time spent in the target quadrant of the Morris water maze during probe trials. Asterisks indicate a significant difference from the control (**P < 0.01).

Discussion

The present study aimed to investigate the effects of a cafeteria diet and simvastatin treatment on spatial learning and memory retention in rats. Several studies have been conducted on the relationship of learning with a high-fat diet, suggesting that learning disorders caused by a high-fat diet can be related to oxidative stress because diet-induced obesity can increase free radicals and oxidative stress in the brain of rodents (15). The possible intervention mechanism in the learning of people with a high-fat diet is probably mediated through insulin, leptin, the brain-derived neurotrophic factor (BDNF) pathways, inflammatory pathways, and blood-brain barrier disorders (16). The results of this study showed that the cafeteria diet had a negative impact on spatial learning and memory retention, as indicated by longer maze completion times and reduced time spent in the target quadrant, respectively. These findings are consistent with previous studies indicating that a high-fat diet can impair cognitive function in rats (5,3)

Ferreira André et al. showed that a cafeteria diet leads to impairments in learning and memory, while a high-sugar diet does not show this effect. They concluded that when it comes to behaviors related to anxiety, spatial learning and memory, and neurogenesis, diets rich in saturated fat and sugar are more harmful to young mice than diets containing high sugar (17). In the present study, it was shown that the treatment of rats fed with a cafeteria diet along with simvastatin improved their learning and memory.

However, treatment with simvastatin at a dose of 50 mg was found to improve both spatial learning and memory retention. This is in line with previous findings that have shown that simvastatin can improve cognitive function in animal models of Alzheimer's disease (12,18). The mechanism underlying these effects is thought to involve the ability of simvastatin to reduce inflammation and oxidative stress in the brain and to promote the growth of new neurons (19).

Interestingly, swimming speed did not appear to be a factor affecting maze completion times. This suggests that the differences in maze completion times between the groups were likely due to differences in spatial learning ability rather than in motor ability.

Conclusion

The present study provided new evidence that a cafeteria diet can impair both spatial learning and memory retention in rats and that simvastatin treatment may be an effective intervention to improve cognitive function in this context. Further studies are needed to determine whether these findings can be translated to humans and to investigate the potential mechanisms underlying the effects of simvastatin on cognitive function.

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Ethical statement

This study was approved by the Ethics Committee of Golestan University of Medical Sciences with an approval code of (IR.GOUMS.REC.1399.344).

Conflicts of interest

The authors declared no conflict of interest.

Author contributions

This article is the result of the thesis of Ms. Niloofar Khanjani, an undergraduate medical student at Golestan University of Medical Sciences. Dr. Hamid Sepehri was the supervisor and responsible for the implementation of this study. Ms. Fatemeh Piri collaborated in the implementation of the experiments and data analysis.

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