Brain Research Bulletin 101 (2014) 45–50

Contents lists available at ScienceDirect

Brain Research Bulletin

journal homepage: www.elsevier.com/locate/brainresbull

Research report

The effect of exercise on carbohydrate preference in female rats

R.J. Keeley*, E.L. Zelinski, L. Fehr, R.J. McDonald

Canadian Centre for Behavioural Neuroscience, Department of Neuroscience, University of Lethbridge, 4401 University Drive, Lethbridge, AB, Canada T1K 3M4

ARTICLE INFO

Article history:
Received 14 August 2013
Received in revised form
19 November 2013
Accepted 22 December 2013
Available online 7 January 2014

Keywords:
Exercise
Diet preference
Rat
Spatial memory

ABSTRACT

Exercise has a myriad of health benefits, including positive effects against heart disease, diabetes, and dementia. Cognitive performance improves following chronic exercise, both in animal models and humans. Studies have examined the effect of exercise on feeding, demonstrating a preference towards increased food consumption. Further, sex differences exist such that females tend to prefer carbohydrates over other macronutrients following exercise. However, no clear effect of exercise on macronutrient or carbohydrate selection has been described in animal or human studies. This research project sought to determine the effect of voluntary exercise on carbohydrate selection in female rats. Preference for a complex (starch) versus a simple (dextrose) carbohydrate was assessed using a discriminative preference to context paradigm in non-exercising and voluntarily exercising female rats. In addition, fasting blood glucose and performance in the Morris water task was examined in order to verify the effects of exercise on performance in this task. Female rats given access to running wheels preferred a context previously associated with starch, whereas females with no running wheel access preferred a context previously associated with dextrose. No changes in blood glucose were observed. However, cognitive differences in the Morris water task were observed such that voluntary exercise allowed rats to find a new location of a hidden platform following 4 days of training to an old platform location. These results suggest that voluntary exercise may decrease preservative behaviors in a spatial navigation task through the facilitation of plasticity mechanisms. This study is the first of its kind to demonstrate the influence of exercise on taste preference for complex and simple carbohydrates with this context conditioning paradigm.

1. Introduction

Increased physical exercise provides protective effects against major chronic illness, including heart disease, stroke, hypertension, breast and colon cancer, type 2 diabetes, and osteoporosis, while physical inactivity is linked to the development of disease states, including obesity, arthritis, and several psychological disorders (Warburton et al., 2007). Exercise also improves cognitive performance in a variety of tasks in normal (Gomez-Pinilla et al., 1998) and aging animals (Aguiar et al., 2011) and following brain injury (Griesbach et al., 2009). Physical activity in conjunction with diet modification has been shown to alter physical attributes and metabolic function, with effects ranging from decreased visceral and subcutaneous adipose tissue and lowered risk for development of type 2 diabetes (Sanz et al., 2010). Given the complex link between diet, exercise and metabolism, it is possible that exercise could affect food selection in a choice paradigm.

Although no clear effect of physical activity (acute, short-term or chronic) on macronutrient selection has been observed in humans (Kanarek et al., 1995; Tremblay and Drapeau, 1999), a trend exists for exercising humans to increase their overall consumption of food and water (Afonso and Eikelboom, 2003). In rats, voluntary wheel running activity results in increased ingestion of carbohydrates but no observable change in fat and protein consumption (Oudot et al., 1996). Sex differences exist such that female rats have a greater appetite than males for sugars (Sclafani et al., 1987).

Foods containing complex carbohydrates increase blood glucose concentrations at slower and more steady rates than simple carbohydrates, such as glucose (Crapo et al., 1981), resulting in a low glycemic index score (Jenkins et al., 1981). Although carbohydrate complexity alone does not determine the rate of glucose absorbance (Wahlqvist et al., 1978), increased consumption of foods that elicit sharp rises in blood sugar have been linked to various disease states in humans (Denova-Gutierrez et al., 2010; Halton et al., 2008; Mela, 1996).

This study examined the effects of voluntary exercise (VE) on food preference in female rats. Preference for either a simple (dextrose) or complex (starch) carbohydrate was assessed in rats with free access to running wheels (VE) or no access to running wheels (NE). Preference was measured using a context conditioning paradigm, which, to our knowledge, has not been used previously to assess context-specific preferences for food subtypes.

* Corresponding author. Tel.: +1 403 394 3985; fax: +1 403 329 2775.
E-mail address: rj.keeley@uleth.ca (R.J. Keeley).

0361-9230/$ – see front matter © 2014 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.brainresbull.2013.12.008

Table 1
Macronutrients in carbohydrate pellets (percent).

Macronutrient	% by weight		% kcal from	
	Starch	Dextrose	Starch	Dextrose
Protein	18.3	18.3	20.2	20.2
Carbohydrate	60.5	60.4	66.9	66.8
Fat	5.2	5.2	12.9	12.9
Total kcal/g = 3.6				

Food consumption during training and establishment of the food context pairings were assessed with a context preference test. The effects of voluntary exercise on spatial memory were evaluated using the Morris water task (MWT). Exercising rats were predicted to prefer foods containing complex carbohydrates, in theory providing steady rates of available blood glucose for exercise (Reaven, 1979), and to exhibit improved cognitive performance in a spatial memory task.

2. Methods

2.1. Subjects

Female Long-Evans rats (~225 g) were purchased from Charles River (Laval, QC) and housed under standard laboratory conditions. This study used exclusively female rats since male rats exhibit greater fluctuations in body weight in response to changes in diet and exercise than do females (Dalderup, 1969). The purpose of the present study was to determine whether voluntary exercise, not adiposity, would result in changes in food preference or cognition thus, the use of males would have confounded the observed results.

Experimental rats ($n = 13$) were given 13 weeks of free access to a running wheel (42.5 cm in diameter) located in their cage. Control rats ($n = 12$) were kept under standard housing conditions. Control and voluntary exercise rats were matched for body weight before the onset of the experimental manipulation. Rats were weighed at 3-day intervals throughout behavioral testing. All procedures were done in accordance to standards set by the Canadian Council on Animal Care and the University of Lethbridge animal welfare committee.

2.2. Carbohydrate pellets

Starch and dextrose pellets were purchased from Harlan Laboratories (Madison, WI). Each type of pellet had near-identical protein, fat and macronutrient composition and only varied significantly in carbohydrate content (Table 1 and Table 2).

2.3. Food restriction

Prior to behavioral testing, rats were put on a restricted feeding schedule in order to maintain motivation in a feeding-reliant paradigm. Following 13 weeks of running wheel or no running wheel access, rats were food restricted to 90% of their *ad libitum* body weight for 7 days. During this 7-day period, rats were simultaneously given standard rat chow (13.0 g ± 0.1 g; Harlan Labs Tekland food) as well as portions of dextrose (3.0 ± 0.1 g) and starch pellets (3.0 ± 0.1 g). After this period, rats were fasted to 85% of their *ad libitum* body weight with standard rat chow until behavioral testing.

2.4. Discriminative preference to context

2.4.1. Apparatus

For the discriminative preference to context task, a similar apparatus to the one implemented for experiments assessing discriminative fear conditioning to context was used (Antoniadis and McDonald, 1999; McDonald et al., 2007) (Fig. 1A). Two chambers, differing in three dimensions (color, shape, and odor) served as the contexts. The chambers were connected by a single alley and could be separated with Plexiglas doors. Rat behavior was recorded during pre-exposure and preference trials.

2.4.2. Pre-exposure

During pre-exposure, rats were given free access to both chambers for a total of 10 min. Dwell time in each chamber was recorded, and initial preference for either chamber was determined by increased time spent in one chamber over the other. Following pre-exposure, starch and dextrose pellets were paired with the contexts associated with the highest and lowest dwell times, respectively. This resulted in all rats save one with starch pellets paired with the black triangle context and dextrose pellets with the white square context.

2.4.3. Training

During 14 days of training, the rats were placed in one of the chambers for 30 min. Roughly 8 g of either starch or dextrose pellets were placed in a small dish at the centre of the chamber. Access to the other chamber was barred using the Plexiglas doors. On alternating days, rats would be exposed to either starch or dextrose pellets in one of the contexts. The food type and context pairings were kept consistent across the training trials.

2.4.4. Preference test with food present

Once training was completed, the rats were assessed in a preference paradigm where they were given free access to either chamber for 10 min with the food pellets present in a small dish in the corresponding chambers as seen on training days. Amount of food eaten and time spent in either chamber was recorded. This preference test not only examined context but also food preference, as assessed by both food eaten and dwell time.

Table 2
Nutritional information ingredient in carbohydrate pellets (g/kg).

Dextrose pellets		Starch pellets	
Formula	g/kg	Formula	g/kg
Casein	207.0	Casein	207.0
DL-Methionine	3.0	DL-Methionine	3.0
Dextrose, monohydrate	658.0	Corn Starch	456.0
Lard	50.0	Maltodextrin	200.0
Cellulose	21.81	Lard	50.0
Mineral Mic, Rogers-Harper	50.0	Cellulose	23.96
Zinc Carbonate	0.04	Mineral Mix, Rogers-Harper	50.0
Vitamin Mix, Teklad	10.0	Zinc Carbonate	0.04
Orange Food Color	0.15	Vitamin Mix, Teklad	10.0