Behavioural Processes 125 (2016) 19–25

Contents lists available at ScienceDirect

Behavioural Processes

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

Can early protein restriction induce the development of binge eating?

Madge Farias Fechine[a], Tássia Karin Borba[a], José Eulálio Cabral-Filho[b], Francisco Bolaños-Jiménez[c], Sandra Lopes-de-Souza[d], Raul Manhães-de-Castro[e,*]

[a] Post-Graduation in Neuropsychiatry and Behavioral Sciences, Health Sciences Center, Federal University of Pernambuco, Recife, Pernambuco, Brazil
[b] Institute of Integrated Medicine Prof. Fernando Figueira, Recife, Pernambuco, Brazil
[c] INRA, UMR1280 Physiologie des Adaptations Nutritionnelles, F-44096 Nantes, France
[d] Department of Anatomy, Health Sciences Center, Federal University of Pernambuco, Recife, Pernambuco, Brazil
[e] Department of Nutrition, Health Sciences Center, Federal University of Pernambuco, Av. Prof. Moraes Rego, 1235, Cidade Universitária, Recife, Pernambuco CEP: 50670901, Brazil

ARTICLE INFO

Article history:
Received 28 April 2015
Received in revised form
30 December 2015
Accepted 1 January 2016
Available online 4 February 2016

Keywords:
Binge eating disorder
Caloric restriction
Hyperphagia
Perinatal undernutrition

ABSTRACT

We tested the hypothesis that perinatal undernourishment is a factor for binge eating. At 52 days rats born from dams fed on 17% protein (Control) or 8% protein (Undernourished) were distributed into four groups, two of which continued to be fed *ad libitum* chow and two were submitted to three consecutive Restricted/Refeeding (R/R) cycles. According to the following schedule: Control Naïve (from mothers fed 17% protein/no restriction phase); Control Restricted (from mothers fed 17% protein/restriction phase); Undernourished Naïve (from mothers fed 8% protein/no restriction phase); and Undernourished Restricted (from mothers fed 8% protein/restriction phase). Each cycle consisted of a restriction phase (in the first four days 40% of the mean daily individual chow intake was offered for consumption), followed by a refeeding phase (4 days of chow *ad libitum*). After the three cycles, all animals were subjected to a feeding test (chow diet and palatable food *ad libitum* for 24 h). During the feeding test, the Undernourished Restricted demonstrated rebound hyperphagia during 2, 4 and 6 h. These results suggest the perinatal undernourishment cannot contribute to a binge eating phenotype.

1. Introduction

Several epidemiological investigations have clearly indicated that an adverse nutritional environment during intrauterine or early postnatal development has deleterious consequences on health, and these effects last throughout the entire lifespan (Gluckman and Hanson, 2004; Hales and Barker, 2001). Individuals exposed to the Dutch famine, which was a 5-month period of extreme food shortage that occurred in the Netherlands in the winter of 1944–1945 during which food rations dropped to as low as 400 calories per day, were more prone to developing obesity, cardio-metabolic disease and breast cancer in adult life (Ravelli et al., 1999). In animals, the development of hypertension, insulin resistance and increased body fat during adulthood can be induced by perinatal nutrient restriction (Langley-Evans, 2001). Interestingly, survivors of World War II who were submitted to caloric restriction in Nazi camps exhibited altered eating patterns and an increased preference for the consumption of high-energy foods (Polivy et al., 1994). Similarly, adult rats born from protein- or nutrient-restricted dams have been shown to exhibit hyperphagia (Orozco-Solís et al., 2009; Vickers et al., 2000).

A high consumption of palatable foods has often been associated with binge eating, which is a maladaptive behavior characterized by the consumption of an unusually large amounts of food over a short periods of time, accompanied by loss of control over eating (American Psychiatric Association, 2013). Foods that are consumed during a binge episode are rich in calories, fat, and/or sugar, and therefore, binge eating is predictive of excessive weight gain and has been linked to obesity (Hudson et al., 2007). In the United States, it affects 3.5% of women, 2% of men and up to 1.6% of adolescents (Swanson et al., 2011). Considering evidence about high prevalence of binge behavior in adolescent and young adult women (American Psychiatric Association, 2013; Hudson et al., 2007; Kjelsås et al., 2004) it is important to approach the problem in animal model observing female rats. Binge eating disorder can be accompanied by anxiety and depression (Sassaroli et al., 2005), which are two mood disorders that have also been shown to be prevalent in individu-

* Corresponding author. Fax: +81 88257635.
E-mail addresses: madgefechine@yahoo.com.br (M.F. Fechine), ftassiakarin@yahoo.com.br (T.K. Borba), eulalio@imip.org.br (J.E. Cabral-Filho), Francisco.Bolanos@univ-nantes.fr (F. Bolaños-Jiménez), sanlopesufpe@gmail.com (S. Lopes-de-Souza), manhaesdecastroraul@gmail.com (R. Manhães-de-Castro).

http://dx.doi.org/10.1016/j.beproc.2016.01.002
0376-6357/

als exposed to nutrient restriction during perinatal development (Brown et al., 2000).

Studies of binge eating have employed different rat models exposed to varying dietary treatments to induce binge access to palatable foods, e.g., three consecutive cycles of Restriction/Refeeding or bingeing access without food deprivation (Artiga et al., 2007; Berner et al., 2008; Boggiano et al., 2005; Corwin and Buda-Levin, 2004; Hagan and Moss, 1997). Many conditions, such as caloric restriction, space-restricted cages, foot-shock stress, increased susceptibility to obesity, limited access to palatable foods and 2 h of daily access (binge access) to combined sugar-fat food without restriction interact to promote binge-eating behaviors (Berner et al., 2008; Boggiano et al., 2007; Hagan et al., 2002; Inoue et al., 1998). Even in unrestricted conditions, palatable foods have been shown to enhance intake during a test meal (Hagan and Moss, 1997) and to result in the alterations of reward pathways related to addiction with effects comparable to those produced by drugs (Colantuoni et al., 2001). Considering the effects of early nutrient restriction on food intake and the development of psychiatric eating disorders, we hypothesized that perinatal undernourishment favors the development of binge eating. The aim of this study was to determine the effects of undernourishment during perinatal development on susceptibility to the development of a binge eating phenotype.

2. Methods

Adolescent female rats (52 days old) born from dams fed a normal or low protein diet throughout gestation and lactation were submitted to a model of binge eating that mimicked the "yo-yo" diet (Boggiano et al., 2007; Cifani et al., 2009; Hagan et al., 2002) typically used by women to lose weight (Reas and Grilo, 2007).

2.1. Animals and maternal diet

All of the experimental procedures were performed in compliance with the recommendations of the Brazilian Society of Neuroscience and were approved by the Animal Experimentation Ethics Committee of the Centre of Biological Sciences of the Federal University of Pernambuco, Brazil (no. 23076.005614/2008-65). Virgin female albino Wistar rats aged 12–18 weeks from the animal colony of the Federal University of Pernambuco were acclimatised to a reverse 12 h light/dark cycle (lights on at 18:00 pm) and maintained under controlled temperature (22–23 °C) with free access to a chow diet (Labina Purina®, Brazil) and water. They were then mated with a male of the same strain and age. After confirmation of mating by the visualization of spermatozoa in the vaginal smear, pregnant dams ($n = 13$) were housed individually and fed either a normal protein diet containing 17 g protein/100 g of food (Control group-6 dams) or a low-protein diet containing 8 g protein/100 g of food (Undernourished group-7 dams) throughout pregnancy and lactation. These diets were isocaloric (Table 1), and both were developed at the Department of Nutrition of the Federal University of Pernambuco according to the AIN-93 (Reeves et al., 1993) recommendations for rodent diets. At birth, the litters from both groups were culled to 8 pups within 12 h of delivery to maintain an approximately 1:1 male to female ratio. At weaning (21 days) two female offspring from each litter were selected at random and maintained in the same cage until 45 days of age receiving chow *ad libitum*. On day 45 the animals were placed into individual cages for 7 days, at which time and the daily mean chow intake calculated.

2.2. Binge eating schedule and experimental groups

At 52 days of age rats born both from dams fed on 17% protein (Control) and from dams fed 8% protein (Undernourished)

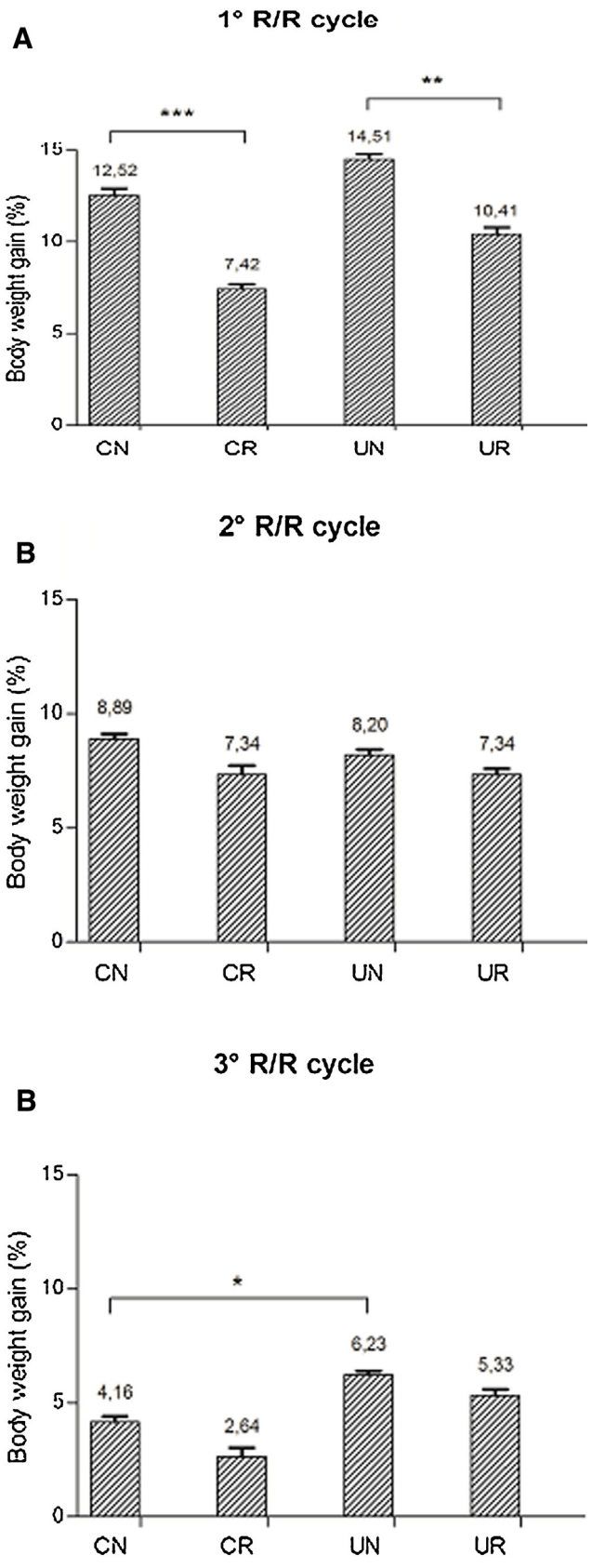

Fig. 1. Body weights change (%) after each one of the three Restriction/Refeeding (R/R) cycles. (A) First R/R cycle: $^{**}p < .01$ (UR *vs.* UN) and $^{***}p < .001$ (CR *vs.* CN); (B) Second R/R cycle: Not significant in any comparison; (C) Third R/R cycle: $^{*}p < .05$ (UN *vs.* CN). Restricted groups [Control (CR) and Undernourished (UR)] and Naïve groups [Control (CN) and Undernourished (UN)]. Data are mean ± SEM.