Indian J Physiol Pharmacol 1991; 35(2): 106-110

THE IMPACT OF EARLY UNDERNUTRITION ON VOLUNTARY FOOD CONSUMPTION IN LATER LIFE OF RATS

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(Received on January 1, 1991)

Abstract : Food consumption patterns were studied during *adlibitum* feeding of rats undernourished for 21 or 60 days after birth. Rats undernourished for 21 days consumed less food than the controls on a whole animal basis. But the food intake was higher during the early part of *adlibitum* feeding when expressed on a unit body weight or metabolic body weight basis, and subsequently became comparable to that of the controls. Male rats undernourished for 60 days showed either comparable (for the whole animal) or higher (in other terms) food consumption, whereas the female rats undernourished for 60 days consumed more food at the beginning of *adlibitum* feeding but less food during the latter part, when compared to their respective controls. The results thus indicate that no single mechanism can completely explain the food intake of undernourished rats during nutritional rehabilitation.

Key words : undernutrition food intake

INTRODUCTION

There is ample scientific evidence to show that undernutrition in the early growth periods of rats bring about physical, physiological and biochemical changes, delay in sexual and skeletal development, and alterations in behaviour (1-5). It is considered that one of the most important behavioural changes that occur is the motivation for voluntary food intake (6) which seems to be more or less permanent for the rest of the life. These altered responses in food consumption of previously undernourished rats appear to be the effect of earlier undernutrition on the developing hypothalamic centers regulating food intake. Some observations indicate a downward setting of the hypothalamic mechanism controlling food intake (7-9) while others suggest an enhanced motivation for food intake (10, 11). The available literature on food intake of previously undernourished rats is controversial (5, 6, 12-15). The problem is further compounded by the way the data has been presented as well as the time and duration of undernutrition and subsequent duration of nutritional rehabilitation. We have studied the voluntary food consumption of previously undernourished rats at different time points during *adlibitum* feeding.

METHODS

Two grades of undernutrition were induced in the growing young rats as follows:

a) Undernutrition from birth to 21 days (UN grade I).

Inbred female Wistar rats were mated to litter mates in pairs. Rat pups born within 24 hours of each other were used and the litter size was made up to 16 to induce undernutrition for the first 21 days before complete weaning. Litter size limited to 5 served as well-fed controls (1). Subsequently, after 21 days, the undernourished rat pups as well as the control animals had access to *adlibitum* laboratory rat diet upto the time they were 180 days old. *Ad-*

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libitum food and water was provided to the lactating mothers during the preweaning 21-day period.

b) Undernutrition from birth to 60 days (UN grade II).

Undernutrition in rat pups was induced for the first 21 days from birth as explained above and subsequently during the postweaning period, the undernutrition was continued upto 60 days of age by providing a restricted amount of rat pellet diet (about 2-3 g per day). Water was given *adlibitum*. This technique was followed to achieve a body weight deficit of approximately 70-75% in the undernourished rats as compared to controls at 60 days of age. Rat pups raised in small litters (5 per dam) served as controls for this group also. The undernourished rats had free access to food after withdrawing the food restriction at 60 days while the control rats were provided unlimited food after 21 days (i.e. after weaning).

Rats of both sexes were included in the study. The laboratory diet (Hindustan Lever, Bombay) supplied energy, 15 kJ/g; protein, 20 g/100 g; crude fibre, 4 g/100 g.

The animals were maintained at a room temperature of 25 ± 2°C and were housed in polypropylene cages measuring 35 × 25 × 15 cm. During the postweaning period of diet restriction as in the case of UN grade II, the experimental rats were kept singly in each cage. When started on *adlibitum* diet, the rats were placed in groups of 4 or 5 in each cage.

Food intake of each previously undernourished rat was assessed at various intervals of time during nutritional rehabilitation along with their age-matched controls when the animals were about 60 or 90, 120 and 180 days old. Each rat from experimental and control group was placed in individual cages for 3-4 days before the actual food intake measurements was started. The pellet diet was mashed into fine powder and mixed with tap water in a proportion of 1:2 (water:food, volume/weight). A known amount of weighed food was presented to the animals at around 09.00 hours on the day food intake measurement was begun and a 24 hour food consumption was noted the next day in the morning around the same time from the difference between the food provided and the food left over after accounting for the changes in moisture content and the spillage. Body weight and food intake of each rat was measured daily for 5 successive days during each event of food intake assessment. The mean values of dry food intake was expressed as kJ/day/animal, kJ/day/100 g body weight and kJ/day/$w^{0.75}$ kg body weight (i.e. metabolic body size). The conversion of food values to kJ was done by using the energy value of the laboratory rat diet which was 15 kJ/g.

Statistical significance of differences between the groups was determined by Students unpaired 't' test and values with $P < 0.05$ were considered statistically significant.

RESULTS

The food intakes of experimental and control rats at various time points have been summarised in Tables I-IV. The average body weight of rats in each group is also given in these Tables. In UN grade I

TABLE I : Energy intakes and body weights of UN grade I male rats (UN) at several time points during nutritional rehabilitation as compared to their age-matched controls (C). Values are Mean ± SEM. n = number of animals studied.

Age at which food intake was assessed	*Group*	*n*	*Body weight (g)*	*kJ/day/animal*	*kJ/day/100 g*	*kJ/day/$w^{0.75}$kg*
Around 60 days	C	5	141.9 ± 7.9	264.9 ± 5.0	175.3 ± 6.7	1071.9 ± 28.0
	UN	8	103.5 ± 4.9°°	215.5 ± 6.7*	210.0 ± 6.7°	1189.1 ± 26.8**
Around 120 days	C	10	248.2 ± 10.5	281.6 ± 9.2	114.2 ± 4.6	806.7 ± 28.0
	UN	13	216.7 ± 5.2*	248.5 ± 4.6°	115.1 ± 2.5	785.3 ± 13.8
Around 180 days	C	10	318.0 ± 11.9	336.0 ± 7.9	106.3 ± 2.1	795.0 ± 11.3
	UN	7	291.4 ± 10.1	311.7 ± 10.5	107.1 ± 2.9	786.2 ± 20.5

*P<0.01, **P<0.02, °P<0.005, °°P<0.001.

TABLE II : Energy intakes and body weights of UN grade I female rats (UN) at several time points during nutritional rehabilitation as compared to their age-matched controls (C)
Values are Mean ± SEM. n = number of animals studied.

Age at which food intake was assessed	*Group*	*n*	*Body weight (g)*	*kJ/day/animal*	*kJ/day/100 g*	*kJ/day/w^0.75 kg*
Around 60 days	C	5	132.7 ± 3.8	220.1 ± 9.2	166.5 ± 10.0	1005.4 ± 55.2
	UN	7	93.5 ± 4.4**	185.4 ± 7.5*	198.7 ± 5.4*	1098.7 ± 27.6*
Around 120 days	C	10	182.4 ± 4.7	230.5 ± 10.0	125.5 ± 3.4	822.2 ± 23.9
	UN	14	152.0 ± 4.2**	205.0 ± 7.1	135.1 ± 2.9	843.5 ± 20.5
Around 180 days	C	10	207.8 ± 3.7	247.3 ± 6.7	119.2 ± 3.4	805.0 ± 20.9
	UN	12	177.3 ± 3.7**	208.4 ± 5.4**	117.6 ± 3.4	764.0 ± 19.3

*P<0.02, **P<0.001.

TABLE III : Energy intakes and body weights of UN grade II male rats (UN) at several time points during nutritional rehabilitation as compared to their age-matched controls (C).
Values are Mean ± SEM. n = number of animals studied.

Age at which food intake was assessed	*Group*	*n*	*Body weight (g)*	*kJ/day/animal*	*kJ/day/100 g*	*kJ/day/w^0.75 kg*
Around 90 days	C	8	240.0 ± 3.8	285.8 ± 9.6	119.5 ± 3.8	834.7 ± 26.4
	UN	7	186.9 ± 9.5**	280.8 ± 11.7	151.0 ± 4.2**	992.9 ± 20.5**
Around 120 days	C	6	287.2 ± 6.7	272.0 ± 5.0	95.0 ± 2.5	694.5 ± 15.1
	UN	8	246.1 ± 9.1*	282.8 ± 7.5	115.5 ± 2.9**	813.0 ± 16.7**
Around 180 days	C	8	303.1 ± 8.8	271.1 ± 9.6	89.5 ± 2.5	664.8 ± 17.2
	UN	8	283.9 ± 9.0	271.5 ± 6.7	95.8 ± 3.4	701.7 ± 20.5**

*P<0.005, **P<0.001.

TABLE IV : Energy intakes and body weights of UN grade II female rats (UN) at several time points during nutritional rehabilitation as compared to their age-matched controls (C).
Values are Mean ± SEM. n = number of animals studied.

Age at which food intake was assessed	*Group*	*n*	*Body weight (g)*	*kJ/day/animal*	*kJ/day/100 g*	*kJ/day/w^0.75 kg*
Around 90 days	C	8	162.9 ± 4.8	196.7 ± 3.8	121.3 ± 3.4	770.3 ± 16.0
	UN	6	134.9 ± 9.0*	233.9 ± 8.8°°	176.2 ± 8.8°°	1063.6 ± 34.3°°
Around 120 days	C	6	171.9 ± 4.5	202.5 ± 8.4	121.3 ± 4.2	777.4 ± 26.8
	UN	7	174.6 ± 4.5	215.9 ± 8.4	120.9 ± 7.1	803.0 ± 34.3
Around 180 days	C	6	187.3 ± 4.8	209.6 ± 6.7	112.1 ± 4.2	739.3 ± 24.7
	UN	8	181.4 ± 4.8	177.4 ± 5.9°	97.9 ± 3.4*	639.7 ± 19.7**

*P<0.02, **P<0.01. °P<0,005, °°P<0.001.

rats of either sex the food consumption was generally less when expressed for the whole animal. During the early part of rehabilitation (around 60 days) the food intake of experimental rats was higher than their controls when expressed per unit body weight or on a metabolic body size basis. Subsequently, the food consumption when expressed in either of these terms was comparable between the groups (Table I, II). In the case of UN grade II rats, the male rats at all points of evaluation showed a food consumption pattern similar to that of their controls on a whole animal basis while in other forms of expression the food intake was generally higher in experimental animals as compared to controls (Table III). It may be noted that in the case of UN grade II female rats, the food consumption, when expressed in any form, was higher in the experimental rats during the early part of rehabilitation (around 90 days) but became comparable between the groups during the subsequent food intake assessment (120 days), and around 180 days of age the experimental rats consumed significantly less food than their controls (Table IV). The body weight of previously undernourished rats of either sex was less at all points of study except in the case of UN grade II female rats, in which it was comparable to the controls around 120 and 180 days of age. The body weight reduction at the termination of food restriction in grade I and II undernourished rats was about 50% and 67% respectively

DISCUSSION

The few reports that are available on voluntary food intakes of previusly undernourished rats during nutritional rehabilitation are conflicting. Pre- or postweaning undernutrition and subsequent *adlibitum* feeding in rats has shown that during rehabilitation the food consumption was comparable to that of controls (13, 14). Some reports on rats undernourished during gestational and/or preweaning period for a variable length of time have shown higher food intakes than in the control group during *adlibitum* feeding (6, 12, 15).

There have been several explanations for the alterations in food intake observed in studies of this type. It is believed that the energy availability (16) and body weight or size of the animal at the time of differentiation of hypothalamic regulatory centers (9, 17), which occurs mainly during the suckling period (18), could influence the process of differentiation and determine the future food intake. Although this basic hypothesis appears true, the nature of such effects is controversial. One group suggests that undernutrition results in a downward setting of the hypothalamic mechanism controlling food intake (7-9), while the other group feels that there is enhanced motivation for food intake in rats undernourished during the suckling period (10, 11).

This disagreement over the issue appears to have arisen partly due to the fashion in which the results have been chosen to be expressed, whether in terms of per animal or per unit body weight or per metabolic body weight ($w^{0.75}$ kg body weight). The expression of food intake for the whole animal is easier to understand, and it is logical to expect that smaller/lighter animals eat less food than their heavier counterparts. However, the present study reveals that this contention may not hold good in all cases. Undernourished rats, when allowed free access to food, may consume higher quantity of food than normal for a certain period of time and may probably be influenced by the intensity and duration of undernutrition. This is possibly due to the fact that in the case of UN grade I rats the time span available for catch-up growth after the initiation of *adlibitum* feeding is considerably longer than that available for UN grade II rats, and hence the food intake is more in rats undernourished for longer periods. This is in keeping with the view that the growth in rats practically stops by the fourth month of age (19), and beyond a certain chronological age growth becomes impossible (20). Hence, the suggestion that body size influences food intake needs reconsideration in this context and such a view may hold good only for rats raised in the normal course.

When the data has been presented on a unit body weight basis, it is presumed that the body composition i.e. the proportion of body weight from fat, protein and water is not very much altered following nutritional deprivation. However, this may not be strictly true (21-23). Smaller animals have higher protein content (24, 25) and therefore will have a tendency to consume more food on a unit body weight basis. This seems to be true only in the early part of rehabilitation.

When the data was expressed as mean energy intake per kg body weight$^{0.75}$ in order to account for the differences in basal metabolic rate inherently due to different body size and its effect on food intake (26) it was found that the experimental rats consumed more food than their control rats during the early part of *adlibitum* feeding, and that later the intake became comparable. However, this is not so in

UN grade II male rats who consumed higher quantities at all points of food intake measurements, and in UN grade II female rats who consumed significantly less food around 180 days. Such variable responses even on a metabolic body weight basis suggest that factors other than body size may be involved in governing the food intake of previously undernourished rats. Since the body composition changes are expected to occur as nutritional level changes, they may influence the food intake which may explain the differences in food intake when expressed in relation to metabolic body size. The differences in food consumption of male and female experimental groups (UN grade II) when compared with their respective controls suggest that sex hormones may also play a role in food intake.

It may thus be concluded that although no single hypothesis completely explains the food intake results obtained in this study, it is most probable that body composition may influence the food intake to a great extent, and body composition estimations may be of value in the interpretation of food intake data.

ACKNOWLEDGEMENTS

The authors acknowledge the senior research fellowship granted to DVM by the Indian Council of Medical Research.

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