EFFECTS OF DISRUPTION OF DIURNAL RHYTHMS IN FOOD INTAKE OF RATS

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Summary : The calorie intake, body weight (bw) mainenance and oral intake of *ad lib* fed (Gr I) and feeding rhythm-disrupted (Gr II) adult rats of either sexes are investigated. Gr I calorie intake (19.2±0.6 cal/100 *gm* bw) and bw (214±5.6 *gms)* were stabilized after 130–140 days of age. Rats of similar age (130–140 days) on feeding rhythm disruption (Gr II) showed initial decrease in calorie intake and bw but 136 days later their bw (224±6.5 *gms*) was similar to Gr I bw (226±9.2 *gms)* though calorie intake (17.5±0.4 cal /100 *gm* bw) was still less as compared Gr I intake. This disparity in calorie intake and bw in Gr II appears to be linked to the adaptive metabolic changes.

The solution and mixed-diets tests showed that oral intake is taste-dependant in Gr II but not in Gr I. Gr II intake was increased on sweet taste and decreased on salt and bitter tastes indicating that feeding rhythm-disruption enhances sensory regulation of intake in contrast to calorie regulation found predominant on free feeding.

Key words: feeding rhythm calorie-intake body weight intake regulation

INTRODUCTION

Rats are nocturnal animals and ingest nearly 60 to 80% of their total daily foo intake during the night (11 and 12). The feeding patterns are shown to parallel th general activity (22 and 23) and blood glucose levels (8). The feeding rhythms ma easily be disrupted by restricting the time of availability of food to a period which fal outside the normal rhythm of the animal. A few such studies have indicated change in metabolic activities (6) as a corollary to the disruption of feeding rhythms. Howeve the long-term effects of feeding rhythm disruption on calorie intake, body weight main tainance, responses to sensory and metabolic properties of the diet are largely unknow The present investigation is intended to meet this lacuna in the knowledge.

MATERIALS AND METHODS

Adult Wistar rats of either sexes and housed in individual cages were used. Group I rats had access to *ad lib* diet whereas Gr II rats were adapted to 3 hr food schedule (09:15 hrs - 12:15 hrs) for a period of 3-4 months. Water was available *ad lib* for both groups. The body weight (bw), food intake and water intake, were measured daily. Both groups of rats were investigated for gustatory responses to 1 hr (08:00 hrs - 9:00 hrs) single bottle tests and to mixed diet intake tests administered randomly. The stock or mixed diet was given to animals immediately after the solution test either for 24 hours (Gr I) or for 3 hours (Gr II) depending on the food schedule. The test solution or mixed diet used, contained either sweet (glucose, sucrose and saccharin) or salty (sodium chloride) or bitter (quinine sulphate) substances in concentrations as shown in Table I. During solution tests, the cage was cleared of food and water, whereas during mixed diet tests the water was available along with the diet. The intake of solution was observed at regular intervals of 5, 15, 30 and 60 min whereas the intake of diet was measured only after the scheduled time of 24 hours (Gr I) or 3 hrs (Gr II).

TABLE I : Components of diets and their caloric density.

Sl. No.	*Diet*	*Components*	*Weight (gms)*	*% by weight*	*Caloric content per gram*	*Total cal/ 1 gram of diet*
1.	Stock	Stock powder	636	63.60	4.20	2.62
		Water	364	36.40	—	
2.	Sucrose	Stock powder	700	70.00	4.20	3.3
		Sucrose	100	10.00	3.98	
		Water	200	20.00	—	
3.	Saccharin	Stock powder	634	63.40	4.20	
		Saccharin	1	0.10	—	2.62
		Water	365	36.50	—	
4.	Salt	Stock powder	720	72.00	4.20	
		Sodium chloride	30	3.00	—	3.0
		Water	250	25.00	—	
5.	Quinine	Stock powder	630	63.00	4.20	
		Quinine	5	0.50	—	2.62
		Water	365	36.50	—	

RESULTS

The calorie intake of Gr I and Gr II rats and their bws are shown in Fig. 1 The Gr I rats showed a rapid bw growth upto the age of 130-140 days after which the bw was almost stabilized at 214±5.6 *gm.* The bw of Gr. II rats (216±4.5 *gm)* at the age of 130 days was comparable to that of Gr I rats when the 3 hr-food schedule was initiated. However, in the first 36 day-period following the initiation of 3-hr food schedule the bw of Gr II rat steadily decreased to the lowest level of 200±8.7 *gm.* After this 36 day period, the Gr II rats showed a steady increase in their bw and at the end of further 100 day period the bw of Gr II rats (224±6.5 *gm)* was similar to the bw of Gr I rats (226±9.2 *gm)* of comparable age (260 days). At 320 days of age the bw of Gr II rats (236.2±7.3 *gm)* even surpassed bw of Gr I rats (234.5±9.8 *gm.)* Parellel to the changes in bw, the calorie intake of Gr I rats showed in general an increase during the period of steep growth in bw and evidenced lowered calorie intake (19.2±0.6/cal 100 *gm* bw) when the growth reached an asymptote. On the other hand, the Gr II rats reduced calorie intake for a period of 8-10 days immediately after they were put on 3-hr food schedule. Later they stabilized food intake at 17.5±0.4 cal/100 *gm* bw (Table II) throughout the period which was significantly less as compared to the intake of Gr I rats ($P<0.05$).

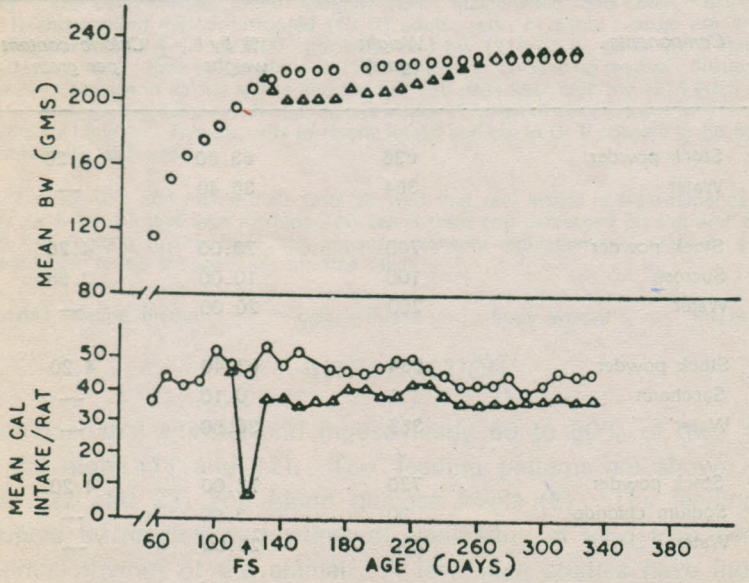

FIG I MEAN BW AND CALORIE INTAKE OF GR I (o—o) AND GR II (Δ—Δ) RATS. (FS↑ = START OF FOOD SCHEDULE)

The results of oral intake of solutions and diets of both Gr I and Gr II rats computed

per 100 *gm* bw are shown in Table II and Table III respectively. Intra group analysis of solution intake showed that the Gr I rats ingested higher amounts of glucose solution (4.5±0.2 *ml)* as compared to their intake of the other three (Saccharin, sodium chloride and quinine sulphate) solutions whereas Gr II rats intake of glucose (4.8±0.1 *ml* was similar to the intake of saccharin (4.3±0.3 *ml*) and was higher as compared to intake of salt (3.6±0.4 *ml)* and of quinine (0.8±0.1 *ml)* solutions. The intergroup analysis showed that the intake of the Gr II rats increased slightly on glucose (4.8±0.1 *ml)* and saccharin (4.3±0.3 *ml),* and significantly on sodium chloride (3.6±0.4 *ml*), but decreased slightly on quinine (0.8±0.1 *ml)* as compared to respective solution intakes of Gr I rats. It is note worthy that the intake of Gr I rats on glucose solution was significantly higher as compared to their intake on saccharin solution, though both glucose and saccharin are sweet in taste. In contrast, the Gr II rats ingested similar amounts on glucose and saccharin solutions.

TABLE II : Solution intake (mean *ml* ± SE/100 *gm* bw) of rats.

Solution	*Gr I*	*Gr II*
Glucose	4.5±0.2	4.8±0.1
Saccharin	3.7±0.2	4.3±0.3
Sodium chloride	2.5±0.1	3.6±0.4
Quinine sulphate	0.9±0.2	0.8±0.1

The calorie intake of both Gr I and Gr II rats on stock diet and on the mixed diets (Table III) showed some notable changes. The calorie intake of Gr I rats on sucrose (19.1±0.9 cal), saccharin (20.5±0.5 cal) and on salt diet (17.7±1.2 cal) was comparable to their intake on stock diet (19.2±0.6 cal). The Gr II rats on the other hand increased their calorie intake on sucrose (22.1±0.9 cal) and saccharin diet (19.2±0.7 cal) but showed a decrease on the salt diet (14.7±0.9 cal) as compared to their intake on stock diet (17.5±0.4 cal). Both Gr I and Gr II rats decreased significantly on the quinine diet, the intakes being 7.6±1.3 cal and 6.8±0.6 cal respectively. Intergroup analysis showed that the calorie intake of Gr. I rats on stock diet (19.2±0.61) was significantly higher as compared to the intake of Gr II rats (17.5±0.4 cal) on the similar stock diet. The Gr I rats intake on salt diet (17.7±1.2 cal) and on quinine diet (7.6±1.3 cal) was also higher as compared to Gr II rats intake on salt (14.7±0.9 cal) and quinine (6.8±0.6 cal) diets, though the increase on quinine diet was only slight. This trend was almost reversed on the addition of sweet taste to diet. The Gr II rats calorie intake on sucrose diet (22.1±0.9 cal) was higher than Gr I calorie intake on sucrose diet (19.1±0.85 cal). On saccharin diet the Gr II intake (19.2±0.7) was similar to Gr I intake (20.5±0.5 cal).

TABLE III : Calorie intake (mean ± SE/100 *gm* bw) of Group I and Group II rats and on stock and test diets.

Diet	*Group I*	*Group II*
Stock	19.2±0.6	17.5±0.4
Sucrose	19.1±0.9	22.1±0.9*
Saccharin	20.5±0.5	19.2±0.7*
Salt	17.7±1.2	14.7±0.9*
Quinine	7.6±1.3*	6.8±0.6*

*P < 0.05 Stock diet intake of the group taken as control.

DISCUSSION

The diurnal eating rhythm of rats was disrupted by restricting the availability of food between 09.15 and 12.15 hrs. The effects of eating rhythm disruption on bw maintenance, calorie, intake, and gustatory responses were investigated. The earlier investigations have shown that the bw of the animals is proportional to its calorie intake (3). However, the Gr II rats, adapted to the 3-hour food schedule for 136 days, had bws (224±6.5 *gms)* similar to the bws of Gr I rats (226±9.2 *gms)* though the calorie intake of Gr II rats (17.5±0.4 cal/100 *gm* bw) was less as compared to the intake of Gr I rats (19.2±0.6 cal/100 *gm* bw). Identical bws on different calorie intakes appear to be due to the changes in the metabolic adaptive changes induced by the disruption in the rhythms of eating (2) or reduction in energy expenditure by "meal eaters" as compared to "nibblers" (4 and 5) or perhaps due to both. As an adaptation to the non-availability of food during species-specific rhythms of eating, the animals are shown to develop efficiency in the conversion of ingested food into bodily stores of lipids and glycogen (9, 17, 18). It has been shown by several investigations (1, 2, 6, 15, 16, 21, 24) that the increase in bw of animals on food schedule is due to the deposition of fat and to a lesser extent to increased glycogen. The increase in bodily stores (lipids and glycogen) of rats on food schedule may be an anticipatory response because the increase in the deposition of fat has also been observed in migrating birds, in hybernants, in early pregnancy of female mammals and in long distance swimmers (7). In addition, early anticipatory systemic responses are also demonstrated for several physiological processes (19 and 20). The fat deposits of animals starved intermittenty may be used by them during periods of starvation. However the mechanisms triggering the changes in metabolic activity favouring the fat deposition are still not clear though ventromedial hypothalamus (VMH) is speculated to lacate such mechanisms (7 and 13). Further, Lepkovsky (14) suggested that the "set point" for energy stores may be shifted to a higher

level during intermittent starvation, which in turn leads to increased deposition of fats. By such a shift in the "set point" the rats on 3-hr food schedule (Gr II) may behave as animals in energy-deficit favouring the conservation of energy.

One of the behaviours of energy-deficit animals as suggested by the model of Jacobs and Sharma (10) is that they show prepotent sensory regulation of intake. The Gr II rats ingested similar amounts of glucose and saccharin solutions (Table I). As both the solutions are sweet for taste though calorically different the ingestive behaviour of Gr II rats could be interpreted to be sensory regulated. This conclusion was further substantiated by mixed diet tests (Table II). The Gr II rats ingested significantly higher amounts of calories on sweet taste and significantly lower amounts on salty and bitter taste as compared to their intake on stock diet. In contrast the Gr I rats calorie intake on sucrose, saccharin and salt mixed diets was similar to their intake on stock diet. Thus both on solution as well as on mixed diet tests the Gr I rats showed predominent calorie regulation of intake.

In short, the present investigation shows that on the disruption of diurnal rhythms of eating in rat, the calorie intake falls sharply and later stabilized at lower level as compared to intake on free feeding. The bw usually followed the fall and rise in calorie intake. However after adaptation to rhythm disruption the bw is disproportionately increased on lowered calorie intake. Further the intake of rhythm-disrupted rats was sensory regulated in contrast to calorie-regulated intake of *ad lib* fed rats though the bws of both the rhythm-disrupted and the *ad lib* fed rats were similar.

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