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Research report

The effect of pre-exposure and recovery type on activity-based anorexia in rats

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ABSTRACT

Activity-based anorexia (ABA) occurs when there is limited access to food and an opportunity to engage in high levels of physical activity. While the ABA effect is well established, the distinct functions of exercise and food restriction in maintaining ABA have not been determined. The current study examined the effect of pre-exposure to a restricted feeding schedule and pre-exposure to a running wheel on the incidence of ABA in 36 rats. Access to food and the running wheel was also varied in the recovery phase of the study in order to establish the effect of these variables on recovery from ABA. Three adaptation conditions (pre-exposed to food restriction, pre-exposed to wheel access and non-exposed) and two recovery conditions (wheel access and food restriction recovery) defined the six groups in the current study. Pre-exposure to food restriction was found to ameliorate the ABA effect during the anorexia phase while pre-exposure to wheel access exacerbated ABA. It was also found that subjects in the wheel access recovery condition gained more weight than the subjects in the food restriction recovery. In food restriction recovery, there was an interaction between the adaptation and recovery condition, with subjects that were pre-exposed to food restriction gaining the most weight. The results of the current study aid in understanding the distinct functions of food restriction and exercise in maintaining and recovering from ABA and have possible implications for the treatment of people diagnosed with some types of anorexia nervosa.

Introduction

Activity-based anorexia (ABA) occurs when there is limited access to food and an opportunity to engage in high levels of physical activity (Routtenberg & Kuznesof, 1967). A classic ABA procedure with rats involves one short feeding period per day and access to a running wheel for the remainder of the day. A control group is exposed to one short feeding period, but they do not have the opportunity to exercise. A paradoxical effect occurs: rats in the experimental group increase running and decrease food intake resulting in significant weight loss, while rats in the control group adjust to the feeding schedule in a short period of time and lose much less weight. Shortly after, Routtenberg (1968) replicated this effect along with other researchers (Spatz & Jones, 1971; Strutt & Stewart, 1970).

In the first experiment of a series (Routtenberg & Kuznesof, 1967), 30 rats lived in home cages attached to running wheels, while six control group rats lived in cages without wheels attached. All subjects were fed 45–60 min daily in the first 9 days of the experiment, and 30 min daily starting from Day 10 until the completion of the study. Subjects with running wheels were denied wheel access during feeding. Weight stability was defined as an animal's weight on Day 4 of any 4-day period being equal to or greater than on Day 1 of the same 4-day period. All of the subjects in the control group attained stable weights within a mean of 15.9 days. In the experimental group, increased running and decreased eating resulted in death within a mean of 13.5 days. The experiment was terminated when all subjects' weights either stabilized or animals died.

Since the original Routtenberg and Kuznesof's (1967) experiments, many studies of ABA focused on understanding its underlying mechanism, and two major theories of activity-based anorexia emerged: the suppression theory (Pierce, Epling, & Boer, 1986) and the adaptation theory (Dwyer & Boakes, 1997). The suppression theory of ABA focuses on the reinforcing values of both food and exercise and how they change when animals are placed on an ABA procedure. According to this theory, eating declines because the reinforcing value of food is reduced when an organism engages in high levels of activity. Concurrently, the reinforcing value of wheel running increases during food restriction.

Pierce et al. (1986) addressed the reinforcing value of running as a function of food deprivation. Rats were trained to lever-press with the opportunity to run in a wheel for 60 s as a reinforcer.

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When lever-pressing was established, the subjects were exposed to a progressively increasing fixed-ratio schedule. The maximum number of lever presses for an opportunity to run was used as a measurement of reinforcing effectiveness of running. The procedure was in place when rats were food deprived and not food deprived. It was found that all subjects lever-pressed more for the opportunity to run when they were exposed to a restricted feeding schedule than when they had free access to food. The results of this experiment suggest that food deprivation is an establishing operation for the increased reinforcing value of running.

The second experiment was designed to determine the effect of running on the reinforcing value of food. The weight of the subjects was reduced to 80% of their ad lib weight. Lever-pressing with food as a reinforcer was shaped using the successive approximations approach. Animals stayed in the cages with running wheels for most of the day during the experiment. The running wheels were either locked or free to turn depending on the experimental condition. During the experimental sessions subjects were exposed to a progressive-ratio schedule with food as a reinforcer. The results were that subjects lever-pressed at smaller ratios when they ran before being placed in the procedure, and that lever-pressing declined significantly in comparison to the sessions when rats did not have the opportunity to run. When the wheel was locked, the total number of lever presses per session ranged from 200 to 452, and the highest ratios completed ranged from 50 to 90 lever presses. Conversely, when rats had access to the wheel throughout the day, the total number of lever presses in experimental sessions ranged between 11 and 112, and the highest ratios completed were between 10 and 40. In summary, the study by Pierce et al. (1986) offers persuasive evidence for the suppression theory of activity-based anorexia, suggesting that the reinforcing value of food declines with an increase in activity level, and the reinforcing value of exercise increases when subjects are food-deprived.

The main alternative explanation to the suppression theory of ABA is the adaptation theory. According to this theory, the opportunity to exercise interferes with adaption to a restricted feeding schedule. Dwyer and Boakes (1997) tested the effect of pre-exposure to a restricted feeding schedule with subjects that were randomly divided into a preadapted and a nonadapted group. During the preadaptation phase subjects in the preadapted group were placed on a 90-min per day feeding schedule. Animals remained in the preadaptation phase until they reached the stability criteria; that is, the rat's weight on Day 4 of any 4-day period was equal to or greater than on Day 1 of the same 4-day period. During this period the nonadapted group had free access to food, and neither group had access to a running wheel. The adaptation phase of the study took 14 days, after which both groups were given access to a running wheel, and the nonadapted group was also placed on a 90-min per day feeding schedule. Animals were removed from the study if their weight dropped and remained below 75% of their ad lib weight for 2 consecutive days.

The results indicated that subjects in the nonadapted group lost significantly more weight than the animals in the preadapted group. While subjects in the preadapted group lost weight when first introduced to the running wheels, their weight began to recover over the course of 7 days. In addition, none of the subjects in the preadapted group reached the removal criteria over the course of the study. In contrast, subjects in the nonadapted group quickly and steadily lost weight. None of the nonadapted subjects' weights recovered, and five out of eight subjects reached the removal criteria at which point the experiment was terminated. The preadapted subjects' food intake slightly dropped when the wheel was introduced, but quickly recovered to pre-running levels and soon began to exceed them. In contrast, the nonadapted subjects' food consumption dramatically dropped when the running wheel was introduced along with the time-restricted feeding schedule. These findings provide strong support for the adaptation theory of ABA, as it can be argued that pre-exposure to a restricted feeding schedule attenuates the ABA effect by providing animals with the opportunity to adapt to the new feeding schedule before gaining access to the wheel.

Several other studies that offer support for the adaptation theory of ABA examined variables that may make it more difficult for the animals to adapt to the restricted feeding schedule. Kanarek and Collier (1983) conducted an experiment that examined the effect of frequency of food access on activity-based anorexia. They predicted that offering more frequent but shorter feedings would mitigate the effect of a restricted feeding schedule as rats tend to eat frequently but in small amounts when they have ad lib access to food and do not have access to a running wheel (Kanarek & Collier, 1979). Such a feeding schedule would approximate the rats' natural feeding pattern and may therefore make it easier to adapt to having limited feeding time. Rats were divided into eight groups differentiated by activity condition (active or inactive) and feeding condition (ad lib food access, one 60-min feeding per day, two 30-min feedings per day or four 15-min feedings per day). At the introduction of the restricted feeding schedule subjects' food intake across groups sharply dropped; however, the extent of the drop was directly related to meal frequency. Animals in the ad lib group continued to maintain their baseline weight. Subjects that had four 15-min feeding periods per day ate the most among the restricted feeding groups and lost the least weight, while rats exposed to one 60-min feeding ate the least and lost the greatest amount of weight. Consistent with the previous studies, rats in the active condition across all restricted feeding groups showed a lower food intake than the animals in the inactive condition.

Dwyer and Boakes (1997) addressed the effect of two additional variables thought to interfere with adaptation to food restriction on weight loss and food intake: time of feeding and time of activity. Rats typically feed during the night (Kersten, Strubbe, & Spiteri, 1980), and Dwyer and Boakes (1997) suggested that interfering with the rats' feeding schedule by giving them access to food in the middle of the day as is typically done in ABA studies may present additional difficulty adjusting to a restricted feeding schedule, especially when paired with access to the running wheel. When Dwyer and Boakes (1997) exposed rats that were fed either in the daytime or at night to a combination of a restricted feeding schedule and access to the wheel, they found that subjects that were fed at night quickly achieved weight stability, while all subjects that were fed during the day reached the removal criteria. They suggested that providing food during the animals' natural feeding time reduces the amount of adaptation necessary to mitigate the ABA effect. That is, they must only adjust to the limited amount of time for feeding and the introduction of exercise, without also having to adjust to the unusual feeding time.

In an experiment exploring the effect of timing of exercise on ABA, Dwyer and Boakes (1997) compared subjects that were provided access to a wheel early in the feeding cycle versus late in the feeding cycle. Animals in both groups were fed between 1:00 pm and 2:30 pm daily. The early group had access to a running wheel from 2:30 pm to 9:00 am daily, for a total of 18.5 h early in the period before the daily feeding. The late group had access to a wheel from 9:00 am to 1:00 pm daily, for 4 h late in and immediately prior to the period before feeding. They found that the early group lost significantly less weight and ate significantly more than the late group. These results are surprising, as they suggest that the timing of activity is a more influential variable than the amount of exercise on food intake, since the amount of wheel access was more than four times greater in the early group. The results of this study offer evidence against the suppression theory of ABA, as according to the suppression theory the higher amount