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Proceeding Paper

Higher Alcohol Preference Is Not Necessarily Linked to Higher Consumption of Palatable Food in Rats †

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Abstract: Alcohol use disorder (AUD) is a chronic relapsing disorder afflicting millions of people worldwide. Malnutrition is frequently associated with AUD, which could be the result of reduced nutritional intake and impairment in the absorption/metabolism of nutrients because of excessive alcohol drinking. Interestingly, the higher consumption of high calorie/palatable foods is reported in recovering alcoholics who stayed sober. However, it is unclear if the higher calorie or rewarding properties of these palatable foods accounted for the protective effect in these conditions. In the present study, we evaluated the palatable food intake in male and female alcohol-preferring (P-rats) and compared it to alcohol-non-preferring rats (NP-rats). Importantly, alcohol-preferring (P-rats) were selectively bred for a higher alcohol preference and are regarded as a well-characterized model of alcoholism. A group of P- and NP-rats received a high-fat diet (40% fat) on four separate days over a two-week period, and their 24 h caloric intake and change in body weight were recorded. Standard chow and water were available unrestricted to all groups for the entire duration of the study. Total caloric intake in both P- and NP-rats was significantly increased on HFD access days compared to chow-only days, an effect observed in both males and females. Further analysis revealed that the total caloric intake in the P-rats was significantly lower compared to the NP-rats, an effect more significant and pronounced in the female group of rats. Furthermore, body weight increase during this period was significantly lower in the P-rats than the NP-rats, an effect more significant and pronounced in the male group of rats. These data not only document the important differences in the palatable diet intake between alcohol-preferring and non-preferring rats and the sex differences but also highlight that a higher alcohol preference does not necessarily equate to a higher intake of high calorie/palatable food.

Keywords: alcohol use disorder; alcohol drinking; high-fat diet; palatable diet; NP- and P-rats

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1. Introduction

Alcohol has been reported to cause 2.6 million deaths worldwide and is the world's largest risk factor for disability and mortality [1]. According to a most recent report, 28.9 million people aged 12 or older had Alcohol Use Disorder (AUD), causing more than 178,000 deaths and costing $249 billion annually [2–4]. AUD frequently co-occurs with eating disorders and other psychiatric disorders [5,6]. Interestingly, food and alcohol intake are controlled by a shared set of neuronal substrates [7,8], and like drugs of abuse, palatable foods are capable of activating brain reward circuitry [9,10].

In addition to impaired physiological and emotional states, malnutrition is frequently reported in alcoholics, which could be a consequence of the decreased intake and absorption of essential nutrients from food following excessive alcohol consumption [11–14]. Interestingly, higher consumption of high calorie/palatable foods is reported in recovering alcoholics who stayed sober [15,16]. However, whether higher calories or the rewarding

properties of these palatable foods accounted for the protective effect in these conditions remains to be identified. Understanding the precise effect of feeding behavior and nutritional status on alcohol drinking could help to design non-pharmacological strategies to combat AUD [13].

Previous studies in laboratory animals assessing the impact of nutritional manipulations on alcohol drinking have obtained mixed results, likely stemming from several experimental intricacies, including the low alcohol consumption in rodents [17]. In addition, AUD is also a multifaceted disorder, and various animal models have been developed to study multiple aspects of alcoholism, as no single animal model can mimic the entire spectrum of this complex human disorder [18,19]. P-rats, obtained through a selective breeding procedure, have been shown to display several proposed criteria, including excessive alcohol drinking, and so are regarded as a suitable model of alcoholism [20–22]. In the present study, we evaluated the palatable food (a moderately high-fat diet) intake in male and female alcohol-preferring (P-rats) and compared it to alcohol-non-preferring rats (NP-rats).

2. Materials and Methods

2.1. Animals

Male and female alcohol-preferring (P) and alcohol-non-preferring (NP) rats (Indiana University) were used in this study. Animals were housed in a vivarium controlled for temperature (~70 F) and humidity (~60%) with a 12 h reverse light–dark cycle. Animals were handled before any experimental manipulation and baseline data (body weight, food intake, water intake) were collected.

2.2. Diets

Standard rodent chow (Tekland-Envigo Diets #2020X, 3.1 kcal/g with 16% of calories from fat and 60% of calories from carbohydrates) and tap water were available to all rats ad libitum at all times. In addition to standard chow, the experimental group also had intermittent access to a high-fat diet (HFD; Research Diets #D03082706, 4.5 kcal/g with 40% of calories from fat, 46% of calories from carbohydrates, and 7.9% of calories from sugar), as described below.

2.3. Experimental Procedure

Male and female NP- and P-rats (n = 3–6/group) received a high-fat diet (40% fat) on four separate days (Tuesdays and Thursdays) over a two-week period, and 24 h caloric intake and change in body weight were recorded. Chow was provided on non-HFD days during the rest of the week. Standard chow and water were available unrestricted to all groups for the entire duration of the study. Food and water were provided ~2 h into the dark cycle, and intake was measured manually after 24 h of access.

3. Results and Discussion

The present study evaluated the total calorie intake between alcohol-preferring (P) and alcohol-non-preferring (NP) male and female rats in the presence of a standard rodent chow and a palatable diet. Consistent with the previous studies, all Int-HFD access groups of rats significantly escalated their caloric intake on HFD access days compared to chow-only days, an effect observed in both NP and P male and female rats (Figure 1A,B). Furthermore, the total food intake (gm and kcal) in the P-rats was significantly lower compared to the NP-rats on HFD access days (Figure 2A,B,E,F), an effect more significant and pronounced in the female group of rats (Figure 2B,F). The area under the curve analysis revealed similar findings (Figure 2C,D,G,H). Likewise, the body weight increase during this period was significantly lower in the P-rats than the NP-rats (Figure 3), an effect more significant and pronounced in the male group of rats (Figure 3C). Collectively, these data highlight sex- and strain-specific differences in the caloric intake between alcohol-preferring and alcohol-non-preferring rats.

A bi-directional positive association between alcohol and high-calorie food has been suggested as earlier clinical studies assessing dietary differences in alcoholics reported a higher intake of calorie-rich food [23–25]. Interestingly, alcoholics display an increased intake of highly palatable food during recovery [15,16]. However, malnutrition, a consequence of the decreased intake and absorption of essential nutrients from food following excessive alcohol consumption [26–28], is frequently reported in alcoholics, along with impaired physiological and emotional states [29–33]. In short, a complex interplay exists among feeding behavior, nutritional status, and alcohol intake that could interact to promote the initiation or maintenance of AUD.

Studies evaluating the impact of altering dietary nutrients on alcohol intake in rodents have obtained inconsistent results. Some observed a high alcohol intake in fat-preferring rats following high-fat diet exposure or the injection of dietary lipids [34–37], while others reported no correlation [38] or even blunted alcohol intake [39]. Similarly, an increased effect and no effect on alcohol drinking have been shown following intermittent access to sugar [40,41]. It is important to note that several critical experimental variables could impact alcohol consumption following dietary manipulations [13,17,42]. Also, rodents typically drink low levels of alcohol, which often does not generate pharmacologically relevant blood alcohol concentrations [43]. These collectively advocate for assessing the relationship between dietary manipulations and alcohol consumption in a suitable animal model of alcoholism. P-rats, obtained through a selective breeding procedure, have been shown to display several of the proposed criteria, including excessive alcohol consumption, to be regarded as a suitable model of alcoholism [20–22]. In addition, these selectively bred alcohol-preferring rats have several behavioral and neurobiological impairments, which may be linked to their excessive alcohol drinking profile [20–22,44]. In the present study, we found that the total caloric intake in the P-group of rats was significantly lower compared to the NP-rats. On a similar note, the body weight increase during this period was also significantly lower in P-rats compared to the NP-rats. These data also align with the reduced nutrient intake under excessive alcohol consumption, as observed in human alcoholics [26–28] and high-alcohol-drinking rodents [45]. Interestingly, studies from our lab have shown that intermittent access to a palatable diet could significantly reduce alcohol drinking in non-dependent rodents [42,46–48], which could have important implications for nutritional interventions in managing problematic alcohol drinking behavior [13,17]. Future studies assessing feeding behavior and the impact of such dietary manipulations in alcohol-dependent states are warranted in this regard.

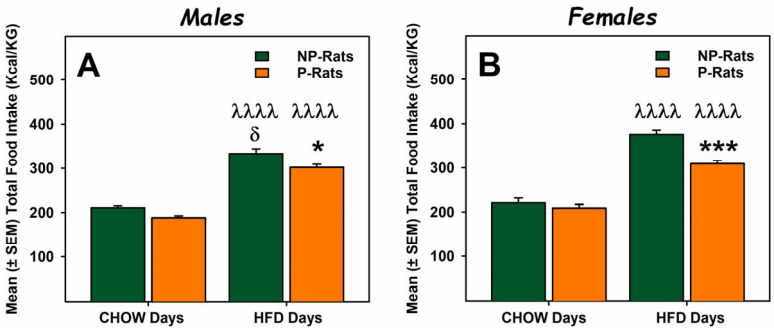

Figure 1. Average total food intake on chow and high-fat access days between NP-rats and P-rats. Mean (± SEM) total food intake (kcal/kg) on CHOW and HFD access days across all testing sessions in (**A**) male and (**B**) female NP- and P-rats are presented. *** $p < 0.001$ and * $p < 0.05$ compared to the NP-rat data for the corresponding dataset. $^{\lambda\lambda\lambda\lambda}$ $p < 0.0001$ compared to the chow days for the corresponding dataset. $^{\delta}$ $p < 0.05$ compared to the female rats for the corresponding dataset (sex differences).

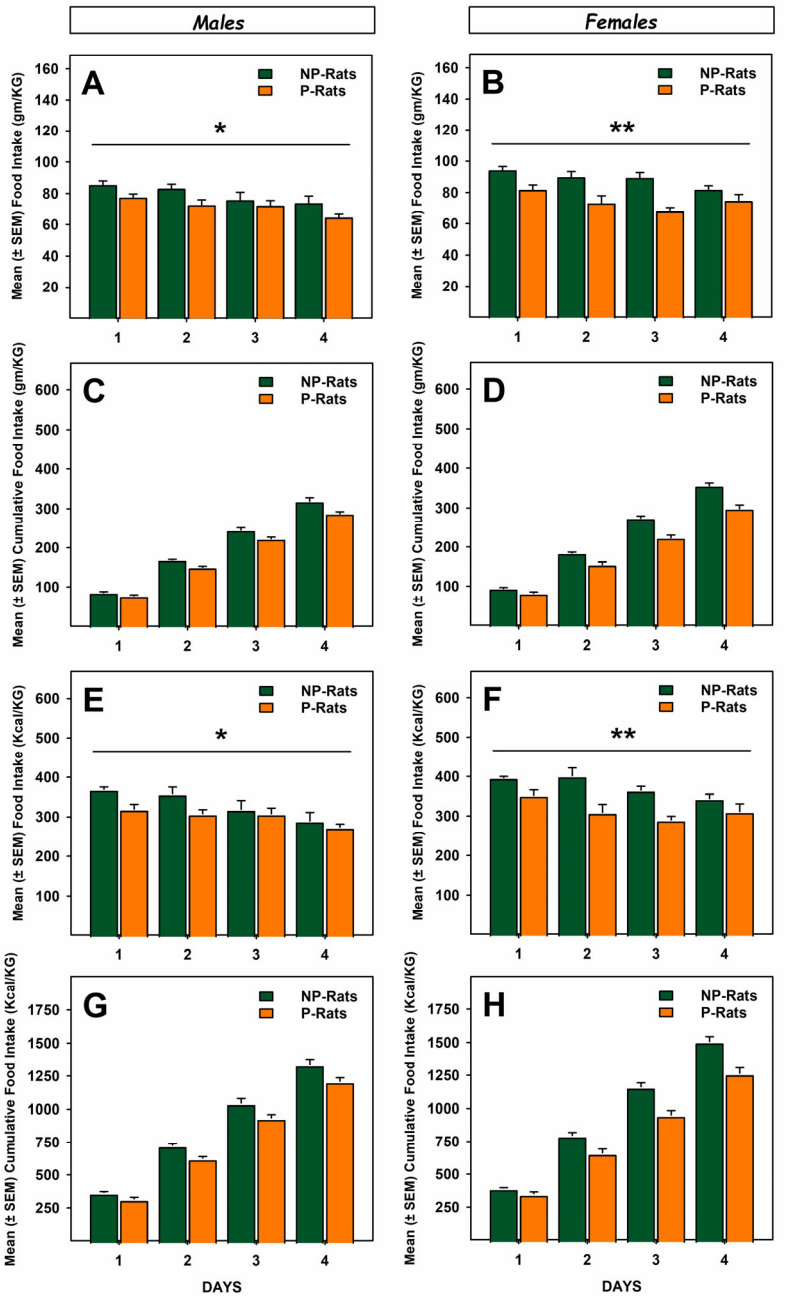

Figure 2. Average total food intake on high-fat access days between male and female NP-rats and P-rats. Mean (± SEM) total food intake in gm/kg for (**A**) male and (**B**) female NP- and P-rats on HFD access days are presented along with the cumulative intake data for the corresponding days (**C**,**D**), respectively. A mixed-model ANOVA ($p < 0.05$) and area under the curve (AUC) analysis confirmed a reduced food intake (grams) in the P-rats compared to the NP-rats in both males [AUC (95% confidence interval); P = 556 (534–578) vs. NP = 617 (595–638)] and females [AUC (95% confidence interval); P = 569 (530–608) vs. NP = 684 (664–705)]. In addition, mean (±SEM) total food intake is also presented in kcal/kg for (**E**) male and (**F**) female NP- and P-rats on HFD access days along with the cumulative intake data for corresponding days (**G**,**H**), respectively. Similar to the food intake in grams, a mixed-model ANOVA ($p < 0.05$) and area under the curve (AUC) analysis confirmed a reduced food intake (kcal) in the P-rats compared to the NP-rats in both males [AUC (95% confidence interval); P = 2330 (2218–2442) vs. NP = 2628 (2517–2739)] and females [AUC (95% confidence interval); P = 2423 (2239–2607) vs. NP = 2913 (2791–3035)]. ** $p < 0.01$ and * $p < 0.05$ between-group effect.

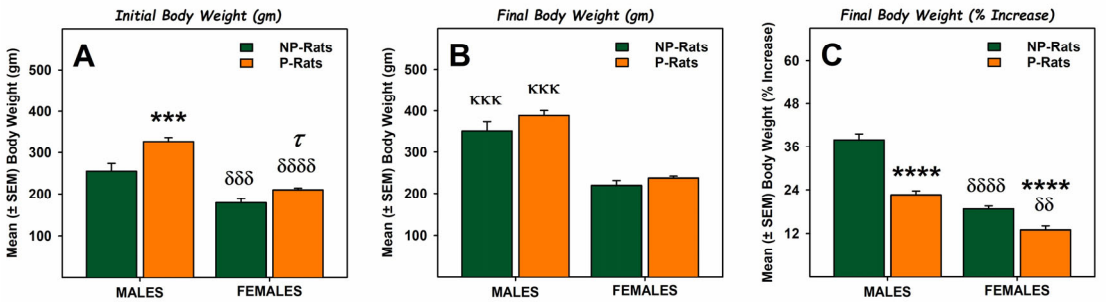

Figure 3. Body weight data for males and female NP-rats and P-rats during testing. Mean (±SEM) (**A**) initial, (**B**) final, and (**C**) percent increase from the baseline body weight data for male and female NP-rats and P-rats are presented. **** $p < 0.0001$, *** $p < 0.001$, and $^{\tau}$ $p = 0.1$ (a trend) between-group (NP- vs. P-rats) effect. $^{\kappa\kappa\kappa}$ $p < 0.001$, compared to the corresponding male dataset in panel (**A**). $^{\delta\delta\delta\delta}$ $p < 0.0001$, $^{\delta\delta\delta}$ $p < 0.001$, and $^{\delta\delta}$ $p < 0.01$, compared to the corresponding male dataset in the respective panel (sex differences).

4. Conclusions

Collectively, the present study documents differences in the palatable food intake between alcohol-preferring (P) and non-preferring (NP) rats, along with the relevant sex-specific disparities, which could have implications in addressing the role of nutrition in alcohol use disorder. These data also demonstrate that a higher alcohol preference does not necessarily equate to a higher intake of high calorie/palatable food.

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Institutional Review Board Statement: The animal study protocol was approved by the Institutional Animal Care and Use Committee at Xavier University of Louisiana on 23 March 2017, with the protocol number 032317-02PH.

Informed Consent Statement: Not applicable.

Data Availability Statement: Dataset is available on request from the authors.

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Conflicts of Interest: The authors declare no conflicts of interest.

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