Selective carbohydrate or protein restriction: effects on subsequent food intake and cravings

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Received 26 September 2005; received in revised form 10 May 2006; accepted 16 May 2006

Abstract

In order to determine the effects of selective food restriction on subsequent food intake and cravings, participants were randomly assigned to one of three conditions: carbohydrate-restriction, protein-restriction, or control (no restriction). Participants in the restriction conditions were asked to restrict their intake of either complex carbohydrates or animal proteins for 3 days, before coming to the laboratory for an experimental session. During the experimental session, participants’ food intake, cravings, and affect were measured. The results indicated that selective food restriction resulted in selective behavioural consequences. Specifically, carbohydrate-restricted participants consumed more of a high-carbohydrate food than did controls or protein-restrictors, in addition to reporting more cravings for high-carbohydrate foods over the restriction period. Protein-restricted participants reported more cravings for high-protein foods over the restriction period, in comparison to controls and carbohydrate-restrictors; however, protein-restricted participants did not consume more of the particular high-protein food presented to them in the laboratory. The roles of dietary restraint and negative affect in influencing cravings and food intake are discussed. Overall, selective food restriction is demonstrated to have negative psychological and behavioural consequences.

Keywords: Carbohydrate restriction; Protein restriction; Food intake; Dietary restraint; Food cravings; Negative affect

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Chronic dieters, or restrained eaters, are characterized by their repeated attempts at weight loss. Frequently these attempts involve either restriction of the total amount of food consumed, or restriction of intake of particular types of foods. However, restrained eaters are generally unsuccessful at losing weight over the long term (Heatherton, Polivy, & Herman, 1991). Research suggests that a restrained eating style is characterized not only by periods of food restriction, but also by periods of overconsumption. Furthermore, this research indicates that, in general, the factors that disinhibit eating in restrained eaters either have no effect on, or reduce the food intake of unrestrained eaters. Disinhibitors for restrained eaters include negative affect (e.g., Heatherton, Striepe, & Wittenberg, 1998), ego threats (e.g., Polivy, Herman, & McFarlane, 1994), and exposure to food cues (Jansen & van den Hout, 1991).

These findings have led to the observation that behavioural inhibition can lead to behavioural excess (Polivy, 1998). With respect to food consumption, chronic inhibition of eating can induce excessive eating and disinhibition of food intake. The specificity of this response, though, is not yet fully understood. It is known that restriction of total food intake is related to subsequent increases in food intake in both humans and animals (e.g., Corwin, 2000; Hunsicker, Mullen, & Martin, 1992; Keys, Brozek, Henschel, Mickelsen, & Taylor, 1950; Laessle, Platte, Schweiger, & Pirke, 1996); however, the effects of restricting only certain foods, which is a method some dieters use in their attempts at weight loss, are less clear. Some dieters may avoid what they consider to be...
Forbidden foods are not necessarily limited to foods that are high in fat, or foods that are considered to be desserts (e.g., cakes and pastries). For example, a study conducted by Knight and Boland (1989) found that foods ranked relatively high on dietary forbiddenness (i.e., foods that are considered forbidden or taboo for individuals on a weight-reduction diet) included foods that are high in complex carbohydrates (CHO) — spaghetti, rolls, and pancakes each received mean scores of 5 or greater on a 9-point scale (with a score of 0 representing a food that is “dietary permitted” and a score of 8 representing a food that is “dietary forbidden”). These rankings somewhat contradict official dietary recommendations (Health Canada, 1997), which state that foods that are high in complex CHO (including pasta and breads/rolls) should compose a significant proportion of daily food intake (5–12 servings per day). In fact, there has been a resurgence of public interest in ‘fad’ diets that recommend minimal consumption of high CHO foods in order to achieve weight loss.

**Effects of selective food restriction on subsequent food intake**

The existing research on the effects of restricting a particular type of food suggests that a rebound effect occurs, with restriction of a particular food resulting in increases in a variety of food-related responses, including intake of the restricted food. Several studies have supported the existence of such a rebound effect for food intake after restricting a particular macronutrient or type of food. For example, Latner and Schwartz (1999) demonstrated that participants who consumed a low-protein/high-CHO liquid lunch had a higher protein intake at dinner, in comparison to controls consuming a mixed protein/CHO lunch, and in comparison to participants who consumed a high-protein/low-CHO lunch. This rebound effect has also been demonstrated in the animal literature: rats and mice maintained on a protein-restricted diet selectively increased their protein intake in comparison to non-protein-restricted rats and mice (DiBattista, 1991; DiBattista, & Holder, 1998).

However, the literature on the effects of CHO-restriction on CHO intake is less consistent, in the animal literature as well as in studies with human participants. Gendall, Joyce and Abbott (1999) demonstrated that the consumption of a low-CHO/high-protein meal resulted in increased consumption of CHO in a group of individuals who were being susceptible to CHO cravings, supporting the presence of a rebound effect. In contrast, Mann and Ward (2001) reported that individuals who had restricted a target food did not increase their consumption of that food after the restriction period ended. Participants in the Mann and Ward study could choose which target food to restrict (as long as it was a food that they both liked and ate frequently), with the most common target foods chosen including foods that are high in complex CHO (e.g., rice, pasta, and cereal). Hence, despite restriction of a specific food, a rebound effect did not take place. The inconsistencies in the rebound effect after selective food restriction extend to the animal literature as well. Although DiBattista (1991) reported that protein-restricted rats increased their intake of protein when available, CHO-restricted rats did not increase their intake of CHO when CHO was available. Thus, the literature concerning a rebound effect for food intake after selective food restriction is mixed. It may also be that this rebound effect is more reliable for protein-restriction than for CHO-restriction.

The role of dietary restraint may be important to consider when assessing the effects of selective food restriction. Recent work in our laboratory (Polivy, Coleman, & Herman, 2005) has demonstrated that restrained eaters who were chocolate-deprived ate more chocolate than did non-chocolate-deprived restrained eaters. However, unrestrained eaters did not exhibit this rebound effect. Thus, it appears that dietary restraint may moderate the effects of selective food restriction. Polivy (1998) indicates that negative consequences result from frequent attempts to inhibit motivations. Specifically, behavioural inhibition can lead to emotional distress, physical illness, and subsequent behavioural excess. Perhaps, restrained eaters are more susceptible to the effects of selective food restriction as a result of their repeated attempts to restrict their food intake, which in turn makes them more susceptible to episodes of disinhibition. While there is some controversy surrounding the link between dietary restraint and overeating (see Lowe, 1993; Yanovski, 1995), it remains important to consider dietary restraint when studying the effects of selective food restriction, in order to determine whether this factor moderates behavioural responses to selective food restriction.

**Effects of selective food restriction on food cravings**

As was previously indicated, selective food restriction may influence a variety of food-related responses, not merely food intake. Another food-related response that may be increased after restriction of a particular food is food cravings. While the amount of food intake can be objectively measured by assessing the weight of food consumed, cravings (or strong urges) for particular foods are relatively subjective. Thus, cravings can be difficult to assess consistently. Despite these difficulties, however, cravings remain an important phenomenon to investigate experimentally, particularly given that cravings may be associated with food intake. For example, food cravings are highly correlated with both emotional eating and susceptibility to hunger (Hill, Weaver, & Blundell, 1991). Furthermore, individuals who experience food cravings report significantly more weight fluctuations than do non-cruvers (Gendall, Sullivan, Joyce, Fear, & Bulik, 1997).

Many of the studies indicating the relationship between food cravings and behaviour utilize correlational analyses
Selective food restriction and negative affect

In addition to the evidence that selective food restriction can influence food intake and food cravings, there is also an apparent link between selective food restriction and mood. This link appears in both naturalistic and laboratory research. De Castro (1987) asked participants to keep food diaries for 9 days, and to record their food intake as well as their mood. Upon analysing the data from the food diaries over the 9-day period, he found a significant correlation between dietary composition and mood. Ingesting a larger proportion of protein in the diet was associated with more depression, whereas ingesting a larger proportion of CHO was associated with less overall depression. Manipulations of meal composition also support the notion that there is an effect of selective food restriction on affect. Keith, O’Keeffe, Blessing, and Wilson (1991) reported that consumption of a low-CHO diet resulted in more depression and anger than did consumption of a diet containing moderate amounts of CHO. More generally, greater CHO intake is associated with improvements in mood (e.g., Benton, 2002; Christensen, 1993).

There is also a link between depression and food intake. For example, one study linked dysphoric mood with CHO cravings, with indications that CHO intake may alleviate depression (Wurtman, 1988). Further research has demonstrated that negative affect is related to overeating (e.g., Stice, Akutagawa, Gaggar, & Agras, 2000). Experimental manipulations of distress have indicated that dysphoria in fact leads to overeating in restrained eaters (e.g., Heatherton et al., 1998; McFarlane, Polivy, & Herman, 1998). It may be that CHO cravings and increased food intake occur in individuals experiencing dysphoria as a result of the potential mood-elevating properties of CHO intake (see Christensen, 1993). However, several studies have failed to demonstrate that consumption of high-CHO foods is more likely to lead to improvements in mood than is consumption of other types of foods (e.g., Christensen & Redig, 1993; Reid & Hammersley, 1995; Rosen, Hunt, Sims, & Bogardus, 1982). Hence, neither the nature of the link between mood and CHO intake nor its causal implications are entirely clear. However, there is a possibility that negative affect mediates the link between CHO restriction and CHO intake: CHO restriction may increase dysphoria, which in turn may increase CHO intake.

Current study–hypotheses and predictions

The existing literature provides some support for the existence of a rebound effect after restriction of a particular type of food; however, this literature is by no means definitive. Although there is some evidence that selective restriction of carbohydrates and protein is associated with subsequent increases in food intake and cravings specifically for the food that was restricted, both the restriction type and period differ across studies. Generally, short-term restrictions have been employed, such as restricting a macronutrient at one meal, and examining total food intake at the following meal (e.g., Latner & Schwartz, 1999). The effects of a one-meal restriction are not necessarily predictive of the effects of a longer-term restriction (over days instead of hours). Furthermore, simple carbohydrates (e.g., sugars) are commonly used in studies investigating the effects of CHO consumption on intake, cravings, and affect (e.g., Gendall et al., 1999; Reid & Hammersley, 1995). Given the assumption that high-CHO foods in general should be avoided by dieters, it is important to determine the effects of restriction of complex as well as simple CHO. Although Mann and Ward (2001) studied the effects of restriction of target foods that included high-CHO foods, such as rice, pasta and bagels, participants were required to avoid eating only one of these foods. This manipulation is not equivalent to restriction of complex CHO overall, as participants had access to a variety of other high-CHO foods. In fact, Mann and Ward suggest that perhaps the rebound effect for eating the restricted item was not found because several other foods...
available during the restriction period would have been able to satisfy desires for the restricted target food.

In order to address these issues, the current study investigated the effects of longer-term restriction (3-day restriction period) of high-carbohydrate or high-protein foods on subsequent food intake, cravings, and affect in both restrained and unrestrained eaters. We predicted that restriction of a specific food would result in subsequent increases in food intake and cravings for the restricted food. Thus, it was predicted that individuals who were CHO-restricted would exhibit increased CHO intake and cravings relative to protein-restricted individuals and controls. Similarly, it was predicted that individuals who were protein-restricted would exhibit increased protein intake and cravings relative to CHO-restricted individuals and controls. However, it was unclear whether CHO and protein restriction would influence participants’ responses equally. Given the finding that high CHO foods are considered to be more “forbidden” (Knight & Boland, 1989), it was hypothesized that CHO restriction would have a greater impact than would protein restriction. Furthermore, it was predicted that there might be differences between restrained and unrestrained eaters in the response to selective food restriction, with restrained eaters demonstrating a stronger response to the restriction than would unrestrained eaters (as in Polivy et al., 2005). Finally, it was predicted that CHO-restricted participants would have higher levels of depression relative to the controls and the protein-restrictors. The effects of CHO restriction on depression were examined, in order to determine if there is a link between CHO-restriction, depression, and increased CHO intake.

Methods

Participants

A total of 89 female undergraduate students completed this study. All participants were run individually between 11:00 a.m. and 6:00 p.m., and were between the ages of 17 and 24 years, with a mean age of 19.5 years. Participants either received one credit towards their mark in an introductory psychology class, or were paid $10 CAD as compensation for their participation.

In accordance with previous research, dietary restraint was measured using the Restraint Scale (Polivy, Herman, & Howard, 1988) and was treated dichotomously, with participants classified as restrained eaters if they scored 15 or above on the scale (n = 42), while those scoring below 15 were classified as unrestrained eaters (n = 47).

All procedures employed in this study were approved by the Social Sciences and Humanities Research Ethics Board at the University of Toronto.

Materials

The foods used in the study were mini croissants, souvlaki chicken seasoned breast fillets (Jane’s Family Foods Ltd., Concord, ON), and No Name mild cheddar cheese (Sunfresh Ltd., Toronto, ON). All food was weighed on a battery-operated digital scale (Acculab, Newton, PA).

Measures

Dietary restraint scale (Polivy et al., 1988)

The restraint scale is a 10-item scale used to assess characteristics associated with chronic dieting (i.e., weight fluctuations and concerns about weight and eating). Individual items are scored from 0 to 3 (or 4, for 5-item questions), with the range of possible scores from 0 to 35. The scale displays internal reliability, test-retest reliability, and predictive validity.

Affect rating scale (Atkinson & Polivy, 1976)

The affect rating scale is a 66-item scale designed to assess current affect. Individual items are scored from 1 to 4, and the scale is broken down into four subscales, assessing joy, hostility, anxiety and depression. For the purposes of this study, analyses were conducted only on the subscales assessing negative affect (i.e. hostility, anxiety and depression scores).

Also included was a questionnaire which was developed for this study in order to assess participants’ usual consumption of foods high in complex CHO (e.g., bread, pasta) and animal protein (e.g., meat, fish, eggs), and the cravings participants experienced for these foods both in general, as well as over the restriction period. Participants’ rated their normal cravings and consumption of the foods, as well as the strength and frequency of their cravings for the foods over the restriction period, on a 5-point scale (with 0 indicating ‘never’ and 4 indicating ‘extremely often’). Participants in the CHO- and protein-restriction conditions were also asked to rate how difficult they found the restriction on a 4-point scale (with 0 indicating ‘not at all’ and 3 indicating ‘extremely’).

Procedure

Participants who signed up for this experiment were pre-screened to ensure that they were not vegetarian and did not have any allergies to the foods that would be tasted during the study. All participants were told that the experiment was being conducted in order to investigate taste sensitivity and flavour discrimination of a variety of foods. In addition, all participants were asked to keep a food diary listing the foods that they ate, along with an
approximate indication of quantities, for 4 days prior to the experimental session. Participants provided consent during the pre-screening process.

Participants were randomly assigned to one of three conditions: control, CHO-restriction, and protein-restriction. Participants assigned to the control group were required only to maintain the food diary before arriving at the experimental session. In addition to maintaining the food diary, those assigned to one of the restriction conditions were asked to change the patterns of the foods they ate for 3 days prior to the experimental session, but were told that they should eat the same amount as they normally would. Specifically, those assigned to the CHO-restriction condition were asked to change the patterns of the foods they ate by abstaining from eating foods high in complex carbohydrates (e.g., bread, grains, potatoes, cakes, cookies) for 3 days, while participants assigned to the protein-restriction condition were asked to abstain from eating animal proteins (i.e., meat, poultry, fish and eggs).

In order to control for the effects of hunger, participants were asked not to eat anything in the 2 h prior to their experimental session. Upon arriving at the experimental session, participants were provided with a consent form to sign. Subsequently, three foods for the taste test were brought in to the testing room and presented to participants. Croissants were included as the high-CHO food, souvlaki chicken as the high-protein food, and mild cheddar cheese was included as a food which no participants were asked to restrict, in order to fit with the cover story that the purpose of the study was to investigate taste sensitivity for a variety of foods. Participants were informed what foods they would be trying, and were instructed to taste each of the foods and complete taste-rating forms. On these forms, participants were asked to rate the qualities of the foods (i.e., saltiness, sweetness, etc.) by placing an “X” on a line that was 152 mm in length, with 0 mm representing ‘not at all’, and 152 mm representing ‘extremely’. Embedded among the ratings was a question asking how good-tasting the participants found the food to be. The experimenter’s interest in participants’ taste sensitivity and ratings of each of the foods was emphasized. Participants were instructed to taste as much as they needed in order to make the ratings, to taste the foods in the order presented, having a sip of water before changing foods, and to do all ratings for each of the foods at once (i.e., not to go back and change their ratings for one food after moving on to the next food). Participants were also told that the task was standardized and that they would be given 10 min to complete their ratings. They were informed that if they had extra time left after they had completed their ratings, they could go back and taste more of the foods if they so desired. All food was presented in bite-sized morsels, heaped onto the plates. The experimenter weighed the plates of food surreptitiously both before and after presentation, in order to determine food intake during the experimental session.

After the 10 min tasting period, the experimenter returned to the testing room, removed the food and rating forms, and provided participants with the cravings/eating habits questionnaire which was developed for this study, the affect rating scale, and the restraint scale. After participants completed these measures, the experimenter probed the participants for any suspicions they had about the purpose of the study, and subsequently debriefed the participants regarding the purpose of the study. The participants’ heights and weights were measured (in order to calculate participants’ body mass index), and the experimenter requested that the students not disclose any details of the experiment to anyone who might later participate.

Data analyses

Participants’ data were excluded from analyses if there was any indication during the debriefing that they suspected that the food was weighed by the experimenter, or if they were not compliant with the experimenter’s instructions with regard to the maintenance of a food diary or the food restriction. A second experimenter, who was blind to the experimental results, reviewed the food diaries of students in the restriction conditions in order to determine if they complied with the instructions to restrict either complex CHO or animal protein. Data for those who violated the instructions of the restriction, but ate less than three individual servings of a restricted item during the 3-day restriction period, were maintained in the analyses. Of the initial 89 participants who completed the study, data from five participants were dropped because they indicated that they were aware that the food was being weighed, and data from an additional seven were dropped because the participants violated the instructions for the food diary and/or the restriction. As a result, the data for a total of 77 participants were included in the final analyses for the study (n = 41 unrestrained and n = 36 restrained eaters).

Unless otherwise indicated, data were analysed using a 3 × 2 multivariate ANOVA, with restriction condition (control, CHO-restricted or protein-restricted) and restraint status (restrained or unrestrained) as the independent variables. Tukey’s post-hoc tests were used to determine differences between means.

Results

Demographic variables

There was a significant effect of restraint on body mass index (BMI) [F (1,70) = 25.08, p < .001], with restrained eaters having a higher BMI (M = 25.2) than did unrestrained eaters (M = 21.4).^2 The pattern of results for the analyses did not differ significantly when BMI was entered as a covariate.
Table 1
Mean food intake during the taste test (± standard error)

<table>
<thead>
<tr>
<th></th>
<th>Croissants</th>
<th>Calories</th>
<th>Chicken</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grams</td>
<td></td>
<td>Grams</td>
<td></td>
</tr>
<tr>
<td>Control N = 27</td>
<td>15.7 (1.89)</td>
<td>54.36 (6.55)</td>
<td>46.41 (4.88)</td>
<td>38.98 (4.10)</td>
</tr>
<tr>
<td>CHO-restricted N = 25</td>
<td>22.64 (3.30)</td>
<td>78.37 (11.42)</td>
<td>45.04 (5.30)</td>
<td>37.83 (4.45)</td>
</tr>
<tr>
<td>Protein-restricted N = 25</td>
<td>15.4 (1.81)</td>
<td>53.31 (6.28)</td>
<td>47.12 (4.17)</td>
<td>39.58 (3.50)</td>
</tr>
</tbody>
</table>

Note: Means in the same column with different superscripts are significantly different from each other ($p < .05$).

**Food intake during the taste test**

Planned comparisons were conducted in order to test the hypotheses that restriction of a particular food would result in rebound eating of that food. Specifically, contrasts were performed in order to test whether the croissant intake of CHO-restrictors was higher than that of protein-restrictors and controls, and whether the chicken intake of protein-restrictors was higher than that of CHO-restricted individuals and controls. The hypothesis that CHO-restricted individuals would eat more of a high-CHO food was supported (see Table 1). The croissant intake of CHO-restrictors was significantly higher than was that of protein-restrictors ($F(1,71) = 4.67, p < .05$), and controls [$F(1,71) = 4.65, p < .05$]. However, the hypothesis that the chicken intake of protein-restrictors would be higher than that of CHO-restrictors and controls was not supported ($F' s < 1$; see Table 1).

In order to test the prediction that restraint status might influence food intake after selective food restriction, a MANOVA was performed, with restriction condition and restraint status entered as the independent variables, and intake of the three foods (croissants, chicken, and cheese) entered as the dependent variables. There was a trend towards a significant effect of restraint on chicken intake [$F(1,71) = 3.56, p < .07$]. Examination of the means indicates that unrestrained eaters ate somewhat more chicken ($M = 50.8$ g) than did restrained eaters ($M = 40.3$ g). However, there was no significant main effect of restraint on croissant intake [$F(1,71) = 2.46, p > .1$] or cheese intake [$F(1,71) = 1.51, p > .1$]. Furthermore, there was no evidence that restraint status interacted with restraint condition on intake of any of the foods (all $F's < 1$).

**Ratings of the foods in the taste test**

A MANOVA was conducted in order to determine if participants’ restriction condition or restraint status influenced their ratings of how good-tasting the three foods were in the taste test. All foods received relatively high mean ratings — the mean ratings for the croissants, chicken, and cheese were 96.1, 99.7, and 91.0, respectively. There was a marginally significant main effect of condition on ratings of the croissants [$F(2,71) = 2.74, p < .08$], with CHO-restrictors having somewhat higher ratings of the croissants than did protein-restrictors; however, this difference did not reach statistical significance. There were no other main effects of either restriction condition or restraint status on ratings of the food, nor were there any significant interactions between the independent variables (all $p's > .1$).

**Data from the cravings/eating habits questionnaire**

**Cravings for foods high in complex CHO**

A MANOVA was conducted in order to simultaneously test the effects of restraint and restriction condition on participants’ scores on the cravings questionnaire which was developed for this study on participants’ cravings for CHO over the restriction period, as well as their usual CHO cravings and intake. There was a significant effect of condition on reported cravings for CHO over the restriction period [$F(2,71) = 10.93, p < .001$], with Tukey’s post hoc tests indicating that CHO-restrictors reported more CHO cravings in the 4 days up to and including the experimental session than did either controls or protein-restrictors ($p < .005$). However, there were also significant effects of condition on reports of usual consumption of CHO [$F(2,71) = 10.81, p < .001$], and on reports of usual cravings for high CHO foods [$F(2,71) = 3.29, p < .05$]. CHO-restrictors reported generally consuming more food high in complex CHO than did both controls ($p < .001$) and protein-restrictors ($p < .001$). CHO-restrictors also reported more frequent usual cravings for CHO than did controls ($p < .04$) but not more than did the protein-restrictors.

There were no significant effects of restraint on usual reported cravings for CHO or frequency of consumption of CHO, nor were there significant restraint by condition interactions for these questions ($F < 1$). However, there was a marginally significant effect of restraint on reported craving for CHO over the restriction period, with restrained eaters reporting somewhat more cravings for CHO than did unrestrained eaters [$F(1,71) = 3.45, p < .07$]. There was no restraint by condition interaction, however [$F < 1$].

\[1\] Due to a violation of homogeneity of variance, the data were subjected to a square root transformation.
Reported cravings for foods high in animal protein

A MANOVA was also conducted in order to assess participants’ responses on the questions on the cravings questionnaire pertaining to foods that are high in animal proteins. There was a significant main effect of restriction condition on cravings for animal protein over the restriction period \(F(2,71) = 10.78, p < .001\), with protein-restricted participants reporting significantly more cravings for protein than did both the controls \(p < .05\) and the CHO-restrictors \(p < .001\) in the 4 days up to and including the experimental session. In contrast to the results obtained for CHO cravings, there was no effect of condition on either usual cravings for animal protein, or usual frequency of consumption of animal protein \(F < 1\).

No significant main effects of restraint were evident on any of the questions pertaining to protein cravings \(F < 1\). However, there was a significant interaction between restriction condition and restraint status for protein cravings over the restriction period \(F(2,71) = 3.40, p < .05\); see Fig. 1). Restrained, but not unrestrained, eaters who were CHO-restricted reported experiencing significantly fewer cravings for protein over the restriction period than did restrained eaters in the control condition \(p < .05\), protein-restricted restrained eaters \(p < .005\), or protein-restricted unrestrained eaters \(p < .005\). There were no significant interactions between restraint and restriction condition for usual protein cravings or protein consumption \(F < 1\).

Reported difficulty of the restriction

Participants assigned to either the CHO- or protein-restriction conditions were asked to report how difficult it was for them to restrict their intake of CHO or protein, respectively, rating the difficulty from “not at all” to “extremely”. A univariate ANOVA with restraint as the independent variable was conducted on this data. The results indicated that there was no significant effect of restraint on the reported difficulty of either the CHO- or the protein-restriction \(F < 1\).

Affect rating scale

Planned comparisons were conducted in order to test the prediction that CHO-restrictors would have increased levels of depression relative to controls and protein-restrictors. This hypothesis was partially supported — CHO-restrictors had higher ratings of depression than did controls \(F(1,67) = 5.47, p < .03\), but did not have higher ratings than protein-restrictors \(F < 1\).

In order to test whether depression-mediated intake of the croissants, a series of regression analyses were conducted using dummy variable coding for the restriction conditions. A marginally significant link was found between CHO restriction and CHO intake \(R^2 = .071, F(2,74) = 2.85, p < .07\), as well as CHO restriction and depression levels \(R^2 = .073, F(2,70) = 2.75, p < .08\). However, the mediational analysis failed to reach significance as there was not a significant link between depression levels and CHO intake \(R^2 = .016, F(1,71) = 1.16, p > .2\). A MANOVA was conducted in order to test whether restraint might have influenced negative affect, or interacted with restriction. All three measures of negative affect (depression, hostility, and anxiety) were entered as dependent variables. There were no significant main effects of condition on the hostility or anxiety subscales of the affect rating scale \(F < 1\). There were also no significant main effects of restraint for participants’ scores on the hostility, depression and anxiety subscales, nor were there significant interactions between restraint and condition on these subscales.

Discussion

An increase in food cravings occurred after both CHO- and protein-restriction, supporting the initial hypotheses pertaining to cravings. CHO-restriction resulted in increases in reported cravings for complex CHO over the restriction period, in comparison to both protein-restrictors and controls. Similarly, protein-restriction was associated with increases in reported cravings for animal proteins over the restriction period, as compared to CHO-restrictors and controls. Furthermore, the increases in reported cravings were specific to the food that was restricted, with CHO-restrictors experiencing increased cravings for CHO only, and protein-restrictors experiencing increased cravings for proteins only. Thus, a rebound effect for cravings was observed after both CHO- and protein-restriction.

The initial hypothesis that a rebound effect for food intake would occur after selective food restriction was partially supported. CHO-restricted participants had a higher intake of croissants than did either control or protein-restricted participants. However, there was no
significant effect of restriction condition on intake of the chicken, indicating that a rebound effect for protein intake did not occur after protein-restriction. Thus, while CHO-restriction was associated with a rebound effect for both food intake and cravings for CHO, protein-restriction was associated only with increased cravings, but not with increased intake of a high-protein food in the experimental session. This finding supports the initial postulation that CHO restriction would have a greater behavioural impact than would protein restriction.

The lack of rebound effect for protein intake after protein-restriction in the current study does not accord with previous studies (e.g., Latner & Schwartz, 1999). Although this discrepancy may reflect differences in methodology between the two studies (e.g., length of restriction, or the manner of manipulating the restriction), it may also reflect differences in the caloric density of the foods chosen for the experimental session in the current study. Whereas the croissants and cheese were high in caloric density (3.5 and 4.1 cal/g, respectively), the chicken was relatively low in caloric density (0.8 cal/g). The chicken was chosen for the high-protein food in the experimental session because it was flavourful, yet non-breaded to avoid confounding the protein condition with elements of complex CHO in the food. However, the fact that the three foods provided were not equicaloric makes it difficult to determine possible underlying mechanisms for the pattern of results. For example, disinhibited eating in restrained eaters often occurs with foods that are considered to be forbidden, or high in calories (see Polivy & Herman, 1985) — thus, it is possible that an interaction between dietary restraint and protein-restriction would have emerged if a high-caloric protein had been presented.

There was limited support for the initial hypothesis that restrained eaters would respond differently to the food restriction than would unrestrained eaters. A marginally significant interaction between restraint status and restriction condition was obtained (see Fig. 1), with CHO-restricted restrained eaters reporting the fewest cravings for proteins over the restriction period. However, contrary to the initial hypotheses, dietary restraint status did not interact with restriction for the measures of food intake. This study does not provide strong evidence that restrained eaters respond differently to selective food restriction of carbohydrates or protein foods than do unrestrained eaters across several dependent measures.

It was hypothesized that negative affect might contribute to a rebound effect on intake (particularly CHO intake) after restriction. This hypothesis was not supported, because although participants in the CHO-restricted group had significantly higher depression scores than controls, the mediational analysis failed to reach statistical significance. However, the methodology of the study limits the ability to assess negative affect as a mediator for intake, given that participants completed the affect rating scale after consuming the croissants. Mood ratings should be obtained both before and after the tasting session in order to determine if there are changes in affect associated with CHO consumption.

A potential confound in the cravings data was the finding of a main effect of condition on participants’ reported usual cravings and consumption of high CHO foods, with CHO-restricted participants reporting more frequent cravings and consumption of high CHO foods, as compared to control and protein-restricted participants. This calls into question the significant effect of condition on cravings for high-CHO foods over the restriction period—the elevated cravings for CHO may not be a result of the restriction but rather a reflection of the fact that we happened by chance to over-assign high CHO cravers to the CHO-restriction condition. In contrast, there was no such effect for protein-restriction, with no significant differences between conditions for reported usual cravings or consumption of animal proteins. It is likely, however, that the effects for CHO restriction were not a result of an unfortunate assignment of CHO cravers to the CHO-restriction condition but rather to a quirk in the procedure: participants in the CHO-restriction condition had more knowledge about foods that are high in CHO because the CHO-restriction instructions listed more foods that must be avoided than did the questions asking about CHO consumption and cravings. In contrast, participants in the other two conditions were not provided with this background, and may have taken the examples provided on the questionnaire (bread and pasta) to be the only types of foods the question was asking about. Thus, it may be that individuals in the CHO-restriction condition were highly aware of their usual consumption, as a result of undergoing the restriction, and answered accordingly on the cravings questionnaire that was provided after the restriction period had ended. In order to avoid this problem with the nature of retrospective data, future research should assess usual intake and cravings for particular foods prior to the assignment of food restriction.

**Future directions and conclusions**

Future research should also extend the length of selective food restriction beyond 3 days, in order to determine whether long-term restrictions (over the period of several weeks) also result in rebound intake and cravings. It is possible that longer-term restrictions will not be associated with rebound effects, as participants perhaps acclimate to selective food restriction (e.g., in low-carbohydrate diets). As a result, the relatively short 3-day period of restriction employed in the current study limits the conclusions that can be drawn with respect to the effects of such longer-term diets.

Although the mechanisms behind the rebound effect for food intake and cravings remain somewhat elusive, this study provides evidence that selective food restriction has both psychological and behavioural consequences. Specifically, CHO and protein restriction both result in subsequent increases in cravings specifically for the
restricted foods. Furthermore, CHO restriction results in subsequent increases in intake of high-CHO food. CHO-restriction in particular may have detrimental effects on psychological well-being, given that CHO-restrictors also reported more depression than did controls. Additional research into the relationship between negative affect, CHO-restriction, and food intake will allow for increased understanding into the factors associated with this rebound effect.

Acknowledgements

This research was supported by a grant from the Social Sciences and Humanities Research Council of Canada to the second and third authors. We would like to thank Loblaw Supermarket for donating the croissants used in this study. A portion of these results was presented at the 111th Annual Convention of the American Psychological Association, Toronto, Ontario, 2003.

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