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EFFECT OF NUTRIENT INTAKE ON PREMENSTRUAL DEPRESSION

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Reprinted from
AMERICAN JOURNAL OF OBSTETRICS AND GYNECOLOGY,
St. Louis

Vol. 161, No. 5, pp. 1228-1234, Nov., 1989

Effect of nutrient intake on premenstrual depression

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We examined the occurrence and coincidence of depressed mood and excessive carbohydrate intake in 19 patients who claimed to suffer from severe premenstrual syndrome and in nine control subjects, all as inpatients, during the early follicular and late luteal phases of their menstrual cycles. Mood was assessed with the Hamilton Depression Scale and an addendum that evaluated fatigue, sociability, appetite, and carbohydrate craving. Calorie and nutrient intakes were measured directly. The subjects with premenstrual syndrome significantly increased calorie intake during the late luteal phase (from 1892 ± 104 to 2395 ± 93 kcal, mean ± SEM); carbohydrate intake increased by 24% from meals and by 43% from snacks. Protein intake failed to change, whereas intake of fat, a fixed constituent of all of the test foods, rose in proportion to calorie intake. The Hamilton Depression Scale and addendum scores rose from 2.0 ± 0.5 to 21.2 ± 0.8 (Hamilton Scale) and from 0.5 ± 0.5 to 10.2 ± 0.6 (addendum) among subjects with premenstrual syndrome during the luteal phase but failed to change among the controls (2.1 ± 0.8 to 2.4 ± 0.8, and 0.4 ± 0.3 to 0.6 ± 0.3). Consumption of a carbohydrate-rich, protein-poor evening test meal during the late luteal phase of the menstrual cycle improved depression, tension, anger, confusion, sadness, fatigue, alertness, and calmness scores ($p < 0.01$) among patients with premenstrual syndrome. No effect of the meal was observed during the follicular phase or among the control subjects during either phase. Because synthesis of brain serotonin, which is known to be involved in mood and appetite, increases after carbohydrate intake, premenstrual syndrome subjects may overconsume carbohydrates in an attempt to improve their dysphoric mood state. (Am J Obstet Gynecol 1989;161:1228-34.)

Key words: Premenstrual syndrome, carbohydrate consumption, mood assessment

The term *premenstrual syndrome* (PMS) or *late luteal phase dysphoric disorder* describes a combination of somatic, appetitive, and behavioral changes that recur each month during the late luteal phase of the menstrual cycle.[1] The most frequently reported symptoms include tension, irritability, depression, anxiety, mood swings, cravings for carbohydrate-rich foods, sleep disturbances, and somatic complaints such as abdominal bloating, peripheral edema, and breast tenderness.[1] Most of the observations with regard to these affective and appetitive symptoms have been subjective, that is, self-reports of changes in mood and appetite and personal recollections of food intake. A few studies have directly measured behavioral[2, 3] or appetitive changes[4-9] throughout the menstrual cycle; however, none has measured food intake and mood concomitantly, during the follicular and luteal phases, among women with severe PMS and symptom-free control subjects.

From the Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology.

Supported in part by a grant from the Center for Brain Sciences and Metabolism Charitable Trust.

Received for publication March 6, 1989; revised May 23, 1989; accepted June 1, 1989.

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6/1/14482

The anecdotal association of carbohydrate craving with premenstrual depression has engendered dietary regimens that substantially decrease the consumption of simple carbohydrates during the luteal phase of the cycle.[3, 9] Such recommendations are based on the assumption that avoidance of simple carbohydrates, especially sweet foods, may diminish or prevent the premenstrual dysphoric mood changes.[3, 9] However, PMS shares certain similarities with a depressive disorder, seasonal affective disorder, in which a mild depression, occurring each fall-winter, is closely linked with an excessive appetite for carbohydrate-rich foods.[10, 11] In contrast to the putative deterioration in mood after excessive carbohydrate intake among women suffering from PMS, individuals diagnosed with seasonal affective disorder have been shown objectively as manifesting significant improvements in mood after consuming carbohydrate-rich, protein-poor test meals.[10] Similarly, obese individuals who intermittently consume excessive amounts of carbohydrates ("carbohydrate cravers") also report improvements in mood after consuming similar carbohydrate-rich test meals.[12] Hence we were interested in determining whether women who claimed to suffer from severe PMS mood changes, especially depression and carbohydrate craving, would in fact exhibit these behaviors when objective measurements of their moods and food intakes were made. We also sought to use objective measurements of mood to de-

termine whether carbohydrate consumption would ameliorate or worsen their premenstrual dysphoria.

In our studies calorie and nutrient intakes from meals and snacks were measured in the inpatient facility of the Massachusetts Institute of Technology Clinical Research Center. Subjects' food intakes and moods were assessed over two 48-hour periods, that is, during the early follicular and the late luteal stages of their menstrual cycles. Subjects were allowed to choose their meal and snack foods from a variety of isocaloric, isofat, carbohydrate-rich, and protein-rich foods, similar to those they normally consume, provided by the research facility. Mood and premenstrual symptoms were assessed during the same test periods by structured psychiatric interviews and self-reports. In a subsequent study women with PMS and control subjects consumed a carbohydrate-rich test meal during the follicular and luteal phases of their cycles, and their moods were examined before and 2 hours after its consumption.

Subjects and method

Subjects were recruited through newspaper, radio, and television advertisements directed toward women who suffered from severe PMS and others who thought themselves to be symptom-free. Initially, potential subjects were told to complete and return by mail a health history questionnaire and a PMS symptom report,[3] which asked them to evaluate changes in their mood, appetite, sleep, and somatic symptoms during the follicular and luteal stages of the menstrual cycle. Subjects who reported significant medical histories or any psychiatric disturbances or the use of any medications (including hormones or oral contraceptives) during the previous 6 months were excluded from future screening. To qualify as a prospective control subject, women had to describe themselves on the self-reports as *never* having had PMS symptoms. Prospective PMS-positive subjects had to indicate on the questionnaire significant changes in mood and appetite between the follicular and late luteal phases of the cycle and also to state that these symptoms had occurred monthly during the prior year. Subjects who qualified were then screened as outpatients at the Massachusetts Institute of Technology Clinical Research Center while in the late luteal phase of the menstrual cycle. At that time they were interviewed about their premenstrual symptoms and underwent a physical examination by a nurse and a gynecologist. Psychometric testing, consisting of a structured psychiatric interview with the Hamilton Depression Scale and a modified addendum to assess changes in fatigue, appetite, carbohydrate craving, and sociability, was used to quantity depressive symptoms. Blood samples were obtained for clinical measurements (complete blood count, thyroid indices, 20-parameter blood profile, pregnancy test). A urinalysis also was done, and an electrocardiogram was obtained if the subject was ≥40 years old. Subjects were also weighed and interviewed by a clinical nutritionist to exclude those with eating disorders. Candidates with PMS were accepted for study if the Hamilton Depression Score during the late luteal phase was ≥20 and if their combined Hamilton Depression Score and addendum scores were ≥30. Subjects were accepted as asymptomatic controls if the Hamilton Depression Score was ≤4 and their combined scores (Hamilton Depression Score plus addendum) were ≤6. All subjects exhibited regular menstrual cycles, ranging from 26 to 35 days. An informed consent form approved by the Massachusetts Institute of Technology Committee on the Use of Humans as Experimental Subjects and by the Clinical Research Center Advisory Committee was signed before participation in any aspect of the studies.

Evaluation of menstrual cycle changes in mood and food intake with the menstrual cycle. Subjects were admitted to the inpatient facility of the Massachusetts Institute of Technology Research Center for two 48-hour periods. One admission was scheduled during the early follicular phase of the cycle (between days 4 and 7); the other admission during the late luteal phase (3 to 5 days before the expected onset of menses). Subjects were instructed to restrict their food to the meals and snacks provided by the Clinical Research Center. Coffee, tea, and decaffeinated beverages were available at all times, and subjects were told to follow their usual patterns of beverage intake. They also were encouraged to follow their usual patterns of physical activity, and appropriate exercise facilities were available.

The mood scores of both groups of subjects were assessed on the morning of their second admission day. Subjects were asked to complete a self-report that assessed mood, appetite, sleep, and somatic complaints during the previous 5 days. The self-report scale used was a modification of the Abraham Premenstrual Symptomatology Questionnaire[5] and consisted of a series of adjectives that could be scored from 0 to 3 (no symptoms to severe). When analyzed, the self-report yielded four factors: mood, appetite, sleep, and somatic complaints. After completion of the self-reports, each subject participated in a structured psychiatric interview conducted by a trained interviewer who used the Hamilton Depression Scale and a four-point addendum (fatigue, sociability, general appetite, carbohydrate craving).

Food intake was measured over a 48-hour period during each stage of the cycle. Subjects were told to come to the dining room for meals but were told to eat as much or as little as they desired. Each meal provided in unlimited quantities three high-carbohydrate (13 to 15 gm carbohydrate) and three high-protein (13 to 15 gm protein) foods. The high carbohydrate foods con-

Table I. Profile of subjects

	Controls	*PMS*
No. of subjects	9	19
Age (yr)	30 ± 2.3	35 ± 1.8
Height (cm)	165 ± 2.4	163 ± 2.0
Weight (kg)	62 ± 3.6	67 ± 3.3
Overweight (%)	−0.1 ± 4.8	9.3 ± 5.4
Progesterone (ng/ml)		
Follicular phase	0.4 ± 0.09	0.4 ± 0.06
Luteal phase	8.8 ± 1.91	7.2 ± 1.75

tained 1 to 2 gm of protein, which was insufficient to block the carbohydrate-induced insulin effect on the plasma tryptophan/neutral amino acid ratio and brain serotonin.[13] The six food items were isocaloric; when necessary, high-fat ingredients, such as butter, cream, or mayonnaise, were added to increase their caloric value and fat content. Each food item contained approximately 120 to 130 calories. The foods were weighed in their containers before they were served, and the containers were reweighed after the meal was completed. The selection of foods presented at each meal remained constant throughout the study and represented foods commonly consumed in this geographic area. Skim milk (4 ounces) was offered at each meal, and a tossed salad and fresh fruit were included with lunch and dinner.

Except during mealtimes, subjects had continuous access to six snacks stored in a refrigerated vending machine. Three of the snacks were high in protein (11 to 12 gm), and three were high in carbohydrate content (12 to 13 gm). The carbohydrate snacks contained <1% protein. All snacks contained between 105 and 110 calories, between 5 and 7 gm of fat, and represented snacks that are available commercially (cookies, candy) or are often eaten as snack foods at home (cheese, cold cuts). The vending machine was interfaced to a microcomputer programmed to allow the subject to obtain any one of the six snacks after typing a personal access code on an attached keyboard. The computer also recorded the identity of the subject, the type of snack removed, and the time of day the snack was obtained. Subjects were instructed to consume each snack as soon as it was obtained and not to save one snack to eat it with another; this was done to prevent them from choosing one snack because it might "taste good" in consumption with another. However, they were allowed to obtain another snack immediately after the first was consumed. They were asked to keep a record of any snack that they took and did not consume; their rooms were checked by the ward housekeeper for hoarding.

Blood samples were obtained during both admissions and were used to determine progesterone levels.

Evaluation of carbohydrate intake on mood and plasma metabolic and endocrine factors. A second group of subjects with PMS and a group of age- and weight-matched controls participated in an outpatient study that measured the effects of a carbohydrate-rich meal on mood and on plasma levels of various metabolites and hormones. The subjects met the same criteria for eligibility as described for the first study.

Women came to the Massachusetts Institute of Technology Clinical Research Center outpatient department once during the early follicular (days 3 to 7) and once during the late luteal (days 25 to 28) stages of the cycle to consume the test carbohydrate meal. However, the order in which meals were consumed was random. On the test day women were not allowed to consume any food or any beverage other than water after 3 PM. At 7 PM they were asked to complete three self-reports of mood and sleepiness: the Profile of Mood States, the Visual Analogue Mood Scale, and the Stanford Sleepiness Scale. The Profile of Mood States is a self-reported mood questionnaire, which when analyzed yields six factors: tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia. The test consists of 65 adjectives, each rated on a five-point scale. The Visual Analogue Mood Scale is a self-report mood questionnaire that uses 32 adjectives to define three mood states: alert, sad, and calm. A horizontal line that is defined by the words "not at all" at one end and "very much" at the other is marked by the subject to indicate the extent to which the moods described by the adjectives are experienced. The Stanford Sleepiness Scale is a seven-item scale designed to quantify the progressive stages of the alertness-sleepiness continuum.

After the completion of the self-reports, a 7 ml blood sample was obtained by venipuncture, and the subjects were then asked to consume a high-carbohydrate, low-protein meal containing 561 calories (112 gm of carbohydrate, 6 gm of protein, and 16 gm of fat). Subjects were told not to consume any food or beverage other than water during the subsequent 2 hours; they sat in a lounge and read or watched television during this time. Two additional blood samples were obtained at 1 and 2 hours after completion of the meal, and the subjects completed the same mood questionnaires as those used before the meal, 1 hour after its completion. Blood samples were analyzed for levels of glucose, insulin, tryptophan, and five neutral amino acids (phenylalanine, isoleucine, leucine, valine, and tyrosine).

Data analyses. Data were stored in a Clinfo data storage base and subsequently analyzed by a two-way analysis of variance with repeated measures. In cases in which a significant interaction was noted, groups of data were separated and analyzed by a one-way analysis of variance with repeated measures by stage.

Results

Study 1. Nineteen subjects with PMS and nine control subjects provided data on food intake and mood during the early follicular and late luteal phases of their men-

Table II. Premenstrual symptom profile

	Control		*PMS*	
	Follicular	*Luteal*	*Follicular*	*Luteal*
Hamilton Depression Scale	2.1 ± 0.80	2.4 ± 0.83	2.0 ± 0.51	21.2 ± 0.80*
Addendum	0.4 ± 0.34	0.6 ± 0.30	0.5 ± 0.50	10.2 ± 0.61*
Subscales				
Work efficiency	0.1 ± 0.11	0.3 ± 0.33	0.0 ± 0.00	2.9 + 0.09*
Fatigue	0.1 + 0.11	0.2 ± 0.15	0.0 ± 0.00	2.6 ± 0.17*
Social withdrawal	0.0 ± 00	0.0 ± 0.0	0.0 ± 0.00	2.5 ± 0.20*
Appetite	0.1 + 0.11	0.1 ± 0.11	0.0 ± 0.00	1.7 ± 0.16*
Carbohydrate cravings	0.2 ± 0.22	0.2 + 0.10	0.1 + 0.06	2.5 + 0.20*
Premenstrual Symptomatology Scale				
Subscales				
Mood	0.8 ± 0.40	2.4 ± 1.0	6.1 ± 2.21	26.1 ± 10.0*
Appetite	0.3 ± 0.30	0.4 + 0.0	1.0 + 0.40	5.6 + 0.20*
Sleep	0.7 ± 0.07	0.7 + 0.07	2.2 + 0.70	7.7 + 1.20*
Physical symptoms	0.14 + 0.10	01.14 + 0.10	2.3 + 0.80	12.3 + 0.80*

Data are reported as means ± SEM. Moods were assessed on the morning of the second inpatient day during the early follicular and late luteal phases of the cycle. The Hamilton Depression Scale and the addendum were administered by a trained rater. The Premenstrual Symptomatology Questionnaire was a self-administered report of mood, appetite, sleep, and somatic complaints.

*Differs from follicular and controls, $p < 0.001$.

strual cycles. The average age of the PMS subjects was 35 ± 1.8 (mean + SEM) years and that of the control subjects 30 ± 2.3 years. All subjects were within 20% of normal weight according to the Metropolitan Life Insurance Tables. Each group as a whole had late luteal plasma progesterone levels ≥5 ng/ml, indicating ovulatory cycles. However, two women in each group showed progesterone levels not greater than 2 ng/ml, suggesting anovulatory cycles (Table I).

The subjects with PMS exhibited significantly elevated depression scores during the late luteal measurement period on both the interviewer-rated Hamilton Depression Scale and its addendum and on the PMS symptom questionnaire (Table II). The late luteal Hamilton Depression Scale and addendun scores were 21 ± 0.8 and 10 ± 0.5, respectively; follicular phase Hamilton Depression Scale and addendum scores were 2 ± 0.5 and 0.5 ± 0.5, respectively. Scores on the Hamilton Depression Scale and addendum subscales that assess symptoms characteristic of PMS were also significantly changed during the late luteal test period; work efficiency decreased ($p < 0.0001$), and fatigue, social withdrawal, general appetite, and carbohydrate craving all increased ($p < 0.0001$) (Table II).

The premenstrual symptoms assessed through the self-report showed similar mood changes; dysphoric mood ratings increased from a follicular score of 6 to 23; appetite from 1 to 5, sleep disturbances from 0.9 to 7, and somatic complaints from 2 to 10 (Table II).

The control subjects exhibited similar and nonsymptomatic ratings of mood, appetite, sleep, and somatic complaints during both phases of the menstrual cycle (Table II).

Subjects with PMS significantly increased their consumption of calories, carbohydrates, and fats during the late luteal phase of the cycle (Table III). Calorie intake from meals increased from 1455 ± 97 to 1729 ± 107 ($p < 0.03$) and from snacks from 437 ± 77 to 666 ± 79 ($p < 0.0024$). The increase was largely accounted for by a specific rise in the consumption of carbohydrate-rich foods. Carbohydrate intake from meals increased by 24% ($p < 0.01$) and from snacks by 43% ($p < 0.003$). The subjects did *not* increase only their intake of sweet carbohydrates; rather, they also consumed more of the starchy carbohydrates such as potatoes, bread, pasta, and rolls.

Preference for and consumption of the protein-rich foods did not differ between the two measurement periods. However, fat intake did increase because the fat contents of all of the foods were similar, and the observed increase in the consumption of the carbohydrate-rich foods of necessity increased fat consumption.

Control subjects consumed similar amounts of calories and nutrients during both phases of the cycle and ate significantly fewer calories, carbohydrates, and fats than subjects with PMS during the late luteal measurement phase (Table III).

Study 2. Eighteen women with PMS and 14 weight- and age-matched controls participated in the second study. The control subjects and those with PMS differed significantly in their behavioral responses to the carbohydrate-rich test meal during the late luteal phase. Subjects with PMS reported significant postmeal *decreases* in depression, tension, anger, confusion, and fatigue on the Profile of Mood States scales. Sleepiness, as measured by the Stanford Sleepiness Scale, decreased but not significantly. The Visual Analogue Mood Scale scores indicated significant *increases* in the calm and alert scales and a significant *decrease* in the sad scale (Table IV). Both premeal and postmeal mood scores were normal during the follicular test

Table III. Calorie and nutrient intakes during the follicular and luteal stages of the menstrual cycle

	Follicular		*Luteal*	
	Control	*PMS*	*Control*	*PMS*
Meals				
Content (kcal)	1530 ± 120	1455 ± 97	1565 ± 144	1729 ± 107*
Protein (gm)	86 ± 9	74 ± 4	84 ± 10	73 ± 4
Carbohydrate (gm)	109 ± 12	114 ± 12	115 ± 12	151 ± 13†
Fat (gm)	83 ± 6	78 ± 5	85 ± 8	92 ± 13
Snacks				
Content (kcal)	555 ± 112	437 ± 77	457 ± 64	666 ± 79†
Protein (gm)	14 ± 2	19 ± 4	10 ± 2	23 ± 3
Carbohydrate (gm)	54 ± 13	34 ± 6	46 ± 9	60 ± 9†
Fat (gm)	43 ± 6	25 ± 4	27 ± 4	37 ± 4*

Data are presented as daily means ± SEM and represent inpatient measurement of food intake over 48 hours during the early follicular and late luteal phases of the menstrual cycle. The data were analyzed by two-way analysis of variance with repeated measures. In cases in which there was a significant interaction, groups were separated and analyzed by stage with a one-way analysis of variance.

*Differs from follicular, $p < 0.054$.

†Differs from follicular, $p < 0.01$.

Table IV. Effect of carbohydrate intake on mood

	Follicular phase		*Luteal phase*	
	Premeal	*Postmeal*	*Premeal*	*Postmeal*
Control subjects				
Profile of Mood States				
Tension	5.0 ± 1.52	3.4 ± 0.67	3.3 ± 0.95	5.0 ± 1.90
Anger	2.6 ± 1.70	1.1 ± 0.51	0.4 ± 0.22	3.0 ± 2.50
Depression	2.6 ± 1.80	1.9 ± 0.88	2.0 ± 0.81	2.3 ± 1.10
Confusion	5.4 ± 1.10	4.6 ± 1.40	4.7 ± 1.20	3.6 ± 0.64
Vigor	13.4 ± 2.11	13.4 ± 1.72	18.0 ± 1.80	15.0 ± 1.74*
Fatigue	8.0 ± 2.13	6.0 ± 1.90	4.4 ± 1.60	5.1 ± 1.50
Visual Analogue Mood Scale				
Sad	11.0 ± 1.80	11.1 ± 1.10	10.0 ± 1.90	12.3 ± 1.70
Alert	35.4 ± 2.60	36.1 ± 2.30	39.0 ± 2.16	38.2 ± 2.15
Calm	23.1 ± 1.40	22.0 ± 1.90	21.1 ± 2.33	20.0 ± 2.55
Stanford Sleepiness Scale	3.0 ± 0.41	2.6 ± 0.40	0.3 ± 0.32	2.4 ± 0.20
PMS subjects				
Profile of Mood States				
Tension	5.5 ± 1.23	4.3 ± 1.03	16.0 ± 1.86	9.3 ± 1.80‡
Anger	2.2 ± 1.00	0.40 ± 0.20†	15.1 ± 3.0	5.0 ± 1.63‡
Depression	4.3 ± 1.70	2.5 ± 1.71	20.0 ± 3.40	11.4 ± 3.05‡
Confusion	4.3 ± 0.60	5.0 ± 0.95	14.5 ± 1.70	9.0 ± 2.00‡
Vigor	16.0 ± 2.0	15.0 ± 2.00	7.0 ± 2.0	9.0 ± 1.51
Fatigue	6.0 ± 1.55	6.2 ± 2.0	15.0 ± 2.0	8.0 ± 2.00‡
Visual Analogue Mood Scale				
Sad	12.4 ± 2.0	10.4 ± 1.61	26.3 ± 2.32	19.5 ± 2.45
Alert	35.0 ± 2.0	36.0 ± 2.43	26.5 ± 1.77	30.1 ± 1.62
Calm	22.0 ± 1.90	19.0 ± 1.81	9.5 ± 2.12	15.1 ± 1.52‡
Stanford Sleepiness Scale	2.7 ± 0.30	3.0 ± 0.40	4.2 ± 0.30	3.4 ± 0.26

Data are represented as means ± SEM. Subjects consumed an early evening meal containing 112 gm of carbohydrate, 6 gm of protein, and 16 gm of fat after a 4-hour fast during the early follicular and late luteal phases of the cycle. Their moods were assessed immediately before the meal and 2 hours after its completion with the Profile of Mood States, Visual Analogue Mood Scale, and Stanford Sleepiness Scale.

*Differs from premeal, $p < 0.03$.

†Differs from premeal, $p < 0.05$.

‡Differs from premeal, $p < 0.01$.

period, and, with the exception of a small but significant decrease in anger (premeal, 2 ± 1.00; postmeal, 0.4 ± 0.20), no mood changes were found at that time.

Control subjects indicated normal mood states both before and after the test meals during both the follicular and luteal phases of their menstrual cycles; however, their ratings of vigor decreased slightly but significantly after the luteal phase test meal (Table IV).

Subjects did not differ in their postprandial glucose, insulin, or amino acid levels at either stage of the cycle, nor did the control and PMS groups as a whole differ from each other.

Comment

The observed eating behaviors of the subjects with PMS differed significantly from those of control subjects during the premenstrual (late luteal) phase of their menstrual cycles. Those with PMS consumed significantly more calories and demonstrated a specific preference for carbohydrate-rich meal and snack foods. In contrast, control subjects did not alter their calorie intakes or their preferences for specific nutrients.

Although several earlier studies have examined food intake throughout the menstrual cycle, few have made direct measurements of eating behavior, and none has concurrently evaluated the mood-related symptoms of the subjects. Nevertheless, findings from several of these studies are similar to those described here. A late luteal phase increase in energy consumption was found by Dalvit-McPhillips,[5] Gallant et al.,[6] Manocha et al.,[7] and Lissner et al.[8] Dalvit-McPhillips[5] also measured nutrient intake and reported a significant increase in postovulatory carbohydrate intake. In the one study in which subjects were classified as either PMS subjects or controls,[7] calorie and nutrient choices were monitored by food records. In contrast to our findings, both control subjects and those with PMS increased calorie intake premenstrually. However, the control subjects differed from those with premenstrual syndrome in the nutrient choices; the former consumed proportionately more protein and fat and the latter consumed proportionately more carbohydrate. Unfortunately, that study used indirect methods of food measurements and did not describe the criteria used to determine the presence of PMS.

The altered food intakes of our subjects with PMS were temporally correlated with substantial depression, fatigue, and decreased work efficiency and sociability. This inverse relationship between premenstrual mood and food intake has been reported in earlier studies by means of subjective measurements of mood and appetite. Both-Orthman et al.[14] found subjects with PMS to be significantly more hungry as their feelings of depression increased. Smith and Sauder[15] also described premenstrual increases in appetite, in particular for carbohydrates, among women who were experiencing significant increases in premenstrual depression.

This parallel increase in carbohydrate intake and depression may be explained in part by the results of our second study. When a carbohydrate-rich meal was consumed during the late luteal phase of the cycle, PMS subjects described themselves as feeling significantly better. Before the meal, on mood questionnaires they indicated substantial depression, anger, tension, fatigue, confusion, and sleepiness. These moods all improved considerably after the meal, as did self-ratings of alertness, vigor, and calmness. In contrast, when the meal was consumed during the follicular stage of the cycle, the subjects did not report negative mood states before its consumption or any changes in mood, with the exception of a small decrease in anger, after its completion.

The absence of differences between the subjects with PMS and control subjects in postprandial plasma glucose, insulin, and amino acid levels indicates that changes in these parameters were not reflecting the observed differences in behavior. (These findings are in agreement with those of Reid et al.[16] who reported no difference in glucose tolerance between asymptomatic women and those with PMS.)

The positive moods that followed intake of the carbohydrate meal during the luteal phase suggest that individuals suffering from PMS may eat carbohydrates for their antidepressant effects. Carbohydrate consumption without protein has been shown to increase serotonin synthesis and release[13] (by increasing the brain's uptake of serotonin's amino acid precursor, tryptophan), and serotonin-releasing brain neurons may be involved in some types of depression. Indeed, of interest in this regard is the avoidance of protein-rich foods whose consumption would inhibit brain uptake of tryptophan and prevent serotonin synthesis and release.[15] Enhancement of serotonin synthesis and neurotransmission by administration of tryptophan or of serotonin-specific drugs has been used to treat some types of depressive illness. Our results indicated that carbohydrate consumption was effective in alleviating many of the luteal mood changes of the subjects and, in that capacity, thus exerted a therapeutic, not a nutritional, effect. Although mood scores were not normalized to those of the follicular phase, the absence of a complete remission may reflect the severity of the subjects' symptoms or the use of a nutrient instead of a drug to relieve them.

It is possible that the positive mood responses described by the subjects after consuming the carbohydrate meal may have been a result of their anticipation that such foods would make them feel better. To minimize the influence of expectation effects, subjects were told that the purpose of the meal was to see whether their glucose levels would change with the menstrual cycle and, if so, whether this might result in mood changes. Indeed, since many of the subjects had been told to avoid carbohydrates premenstrually (because of a possible connection between abnormal changes in blood glucose levels and mood[3]), many of the subjects assumed they would experience a worsening, not an

improvement in their mood. Moreover, if the subjects had anticipated particular mood changes, they would have been most susceptible during the first testing period regardless of the stage of the cycle. No such order effects were found. Subjects who consumed the meal for the first time when they were in the follicular phase did not differ in their luteal phase mood responses from subjects who consumed the first test meal when they were in the luteal phase.

The positive effects of a carbohydrate meal on mood have previously been observed among obese carbohydrate cravers who periodically increase their intake of carbohydrate-rich snacks[12] and among individuals suffering from seasonal affective disorder[10] who eat excessive amounts of carbohydrate-rich foods during the late fall and winter. These groups, like the premenstrually depressed women, also tend to avoid protein-rich foods during periods of increased carbohydrate intake.

The concurrent carbohydrate craving and depression described here suggest that serotonin is involved in the symptoms of premenstrual depression and offer the possibility that interventions which, like carbohydrate intake itself, increase the synthesis or release of this neurotransmitter may be useful therapeutically.

Addendum

We obtained 24-hour levels of melatonin and prolactin, as well as estrogen and progesterone, in control and PMS subjects and no differences were found between the groups. Serotonin levels in the blood do not indicate brain levels as serotonin is found in a variety of foods and diet alone can alter blood levels. Blood serotonin does not pass into the brain; the only way to establish brain levels is through direct assay or through cerebrospinal metabolites. Understandably, neither assay was done on our healthy subjects.

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A complete list of references is available from the authors on request.