ORIGINAL RESEARCH

CURRENT DEVELOPMENTS IN NUTRITION

Eating Behavior and Qualitative Assessments

Liking and Acceptability of Whole Grains Increases with a 6-Week Exposure but Preferences for Foods Varying in Taste and Fat Content Are Not Altered: A Randomized Controlled Trial

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ABSTRACT

Background: Since 2005, the Dietary Guidelines for Americans have recommended consuming at least half of total grains as whole grains (WGs) for optimal health benefits; however, consumption of WGs falls far short of recommended amounts.

Objective: This study aimed to evaluate the effect of mere exposure to WGs on liking, acceptability, and consumption of WG foods and to determine if exposure to WG would influence liking and wanting for other foods varying in fat content and sweet taste.

Methods: Healthy, self-identified low WG consumers ($n = 45$) were randomly assigned to either a 6-wk WG intervention or a refined grain (RG) control condition during which they received a weekly market basket of grain products to incorporate into daily meals and snacks. Consumption of grain products was measured by weekly logs and weigh-backs. A sensory evaluation protocol was conducted at baseline and week 6 to evaluate changes in perception of grain products. Computer tasks designed to measure liking and wanting for other foods varying in high/low-fat content and sweet/savory taste were also completed at baseline and week 6.

Results: Participants in the WG group significantly increased WG consumption. Exposure to WG products resulted in improved ratings of liking, flavor, texture, and willingness to include WG in the regular diet. No significant changes in liking or wanting for foods representing high-fat sweet (HFSW), low-fat sweet (LFSW), high-fat savory (HFSA), or low-fat savory (LFSA) categories were found in the WG group. In contrast, exposure to RG foods resulted in an increased explicit wanting for HFSW and LFSW and a decreased wanting for HFSA foods.

Conclusions: Mere exposure to WG foods represents a feasible and easily applied behavioral strategy for increasing consumption of WGs. Encouraging consumers to focus on enjoyment of the taste may be more effective than emphasizing the health benefits of WG consumption. This trial was registered at clinicaltrials.gov as NCT01403857. *Curr Dev Nutr* 2020;4:nzaa023.

Keywords: high-fat savory, high-fat sweet, implicit and explicit, liking and wanting, low-fat savory, low-fat sweet, low whole grain consumers, mere exposure, sensory evaluation, whole grain consumption

Published by Oxford University Press on behalf of the American Society for Nutrition 2020. This work is written by (a) US Government employee(s) and is in the public domain in the US.

Manuscript received September 20, 2019. Initial review completed February 3, 2020. Revision accepted February 13, 2020. Published online 0, 2020.

Supported by the USDA Intramural Funds Project (5306-51530-019 and 2032-51530-022).

Author disclosures: The authors report no conflicts of interest.

Supplemental Figure 1 is available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/cdn/.

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Abbreviations used: DGA, Dietary Guidelines for Americans; HFSA, high-fat savory; HFSW, high-fat sweet; LFPQ, Leeds Food Preference Questionnaire; LFSA, low-fat savory; LFSW, low-fat sweet; PROP, 6-n-propylthiouracil, RG, refined grain; RT, reaction time; SLB, standardized light breakfast; SSS, sensory specific satiety; VAS, visual analogue scale; WG, whole grain; WHNRC, Western Human Nutrition Research Center.

Introduction

Since 2005, the Dietary Guidelines for Americans (DGA) have recommended that at least half of all grains consumed be whole grains (WGs) (1). Adding to the 2005 DGA, the 2010 and 2015 DGAs recommend consumption of ≥3 ounce-equivalents/servings of WG per day for individuals whose energy needs are ≥ 2000 kcal/d (2, 3). Greater WG intake is associated with better weight control (4–6) and reduced risks of major chronic diseases such as cardiovascular disease (7, 8), type 2 diabetes (9, 10), inflammatory diseases (11), and certain cancers (8, 12). Although Americans meet or exceed the DGA recommendation for total grain intake, WG intake falls far short of recommended amounts, with most individuals consuming <1 serving per day (4, 13, 14). Reported barriers to adequate WG consumption include poor taste and texture relative to refined grain (RG) products, inability to identify WG products at the point of purchase, lack of knowledge of the health benefits of WG, and less availability and higher cost of WG products (14–16).

Research into sensory attributes influencing acceptance of WGs points to bitter taste as the primary barrier to adequate intake (17–19). However, research into consumer acceptance of novel or less-liked foods indicates that through repeated exposure, initially less palatable or unfamiliar foods ultimately achieve higher acceptance, i.e., the "mere exposure" effect (20–22). Results from these studies suggest the possibility that repeatedly exposing individuals to the taste of WG products can increase their liking and acceptance of these products and ultimately increase WG intake to meet DGA-recommended amounts. Other evidence suggests that exposure to one healthy food may carry over to preference for other healthy foods, conferring a "halo effect" (21, 23, 24).

When the drivers of food choice behavior are evaluated, the difference between liking and wanting is important to consider. Liking refers to the hedonic aspect of a food whereas wanting refers to incentive salience, or the motivation to acquire a particular food (25, 26); both aspects of food reward are important drivers of food choice (27–29). Liking and wanting can be further differentiated into implicit and explicit processes, corresponding with the extent to which these drivers of food choice are available to conscious introspection (27, 30). Finlayson and colleagues conducted a series of experiments demonstrating the differentiation between implicit and explicit liking and wanting and their relative contributions to food choice (30, 31). In 1 study, the authors found that enhanced implicit wanting for food stimuli was associated with compensatory eating after an exercise bout, but hunger and explicit liking were not (31). This demonstrates that while explicit liking for foods might be considered a main driver of food choice and consumption, implicit processes may play a greater role in ingestive behavior. Moreover, implicit and explicit liking and wanting for foods varying along the gradients of sweet-savory taste and high-low-fat content have been shown to be differentially influenced by dietary manipulation of macronutrient composition of test meals (32) and sweet- or savory-tasting drinks (33). Griffioen-Roose and colleagues tested the effects of preloads varying in protein content and taste on ad libitum energy intake at a subsequent lunch buffet consisting of foods varying in protein content (high/low) and taste (sweet/savory) (32). In addition, they administered a computerized test to assess implicit and explicit components of food reward (31). In that study, both food intake and choice correlated with explicit and implicit processes but in differing amounts. While there was no effect of the protein content of the preloads on food choice at the buffet, there was an effect of taste whereby after the savory preloads, choice and intake of sweet foods was greater. Energy intake at the buffet was predicted by explicit (conscious) wanting, while selection of a specific food category was more predicted by implicit (subconscious) wanting. It is not known how exposure to WGs could affect explicit and implicit liking and wanting for foods varying in fat content (high/low) and taste (sweet/savory).

The current research employed standard sensory evaluation tests to measure specific aspects of the perception of WG products that influence acceptance, including overall liking, flavor, and willingness to purchase and consume at home. In addition to documenting changes in the sensory aspects related to the acceptance of WG, we sought to determine potential changes in the explicit liking as well as explicit and implicit wanting for hedonically appealing foods. Exposure to healthy foods such as WGs may present a strategy for increasing not only consumption of WGs but also of other nutritious foods. We hypothesized that repeated exposure to WG foods would result in increased liking and acceptance of WGs and that the halo effect of prolonged exposure to this healthy food group would decrease wanting for high-fat foods.

Methods

Participants

Healthy men and women, aged 20–45 y, with a BMI between 18.5 and 35.9 kg/m^2 and stable body weight (within ±3 kg) for the previous 6 mo were recruited from the general areas of Davis, Dixon, Vacaville, and Sacramento, California. To be eligible for enrollment in the study, participants prepared and ate the majority of their meals at home, and their self-reported habitual consumption of WGs was ≤1 serving/d. Participants agreed to incorporate provided study foods into their daily diet for the duration of the 6-wk intervention. Participants also agreed to continue their usual physical activity practices. Exclusion criteria included current dieting to lose weight; pregnancy currently or within the past 6 mo; diagnosis of type 1 or 2 diabetes; gastrointestinal diseases, including malabsorption syndromes and inflammatory disorders, colorectal cancer, celiac disease, diverticulitis, or Crohn disease; allergies to any study foods; regular use of colonics or laxatives; recent (within 3 mo) use of antibiotics or appetite suppressants; and regular use of tobacco products. Eligible participants were stratified by 6-n-propylthiouracil (PROP) taster status (assessed at the screening visit), with PROP status separated into 3 categories: nontaster, medium taster, and supertaster. We questioned whether supertasters, capable of detecting bitter-tasting compounds in WGs at much lower concentrations than medium and nontasters can detect (17–19), would show an increase in liking of WGs after mere exposure or, alternatively, if taster status would predict liking and consumption of provided WG products. Within each stratum, randomization sequences were generated a priori using a permuted block size of 3. Within each block, allocation was assigned in a 2:1 ratio in favor of the WG intervention, because we were mainly interested in the results of the WG exposure. The study was reviewed and approved by the University of California, Davis, Institutional Review Board. All participants provided written informed consent and received monetary compensation for their participation. This trial was registered at clinicaltrials.gov as NCT01403857.

Study design

This study was a 6-wk, randomized, assessor-blinded, parallel-design trial to determine if daily exposure to WGs could increase consumption to meet DGA-recommended intake in free-living conditions. Participants completed 2 study visits, the first prior to and the second immediately following the 6-wk intervention. For each study visit, participants arrived at the USDA, Agricultural Research Service, Western Human Nutrition Research Center (WHNRC) after an overnight fast and were provided with a standardized light breakfast (SLB). The purpose of providing the SLB was to ensure that all participants had eaten the same foods within the same amount of time before performing the sensory evaluation testing. The breakfast (376 kcal, 52% carbohydrate, 14% protein, and 34% fat) included fresh red Gala apple slices, creamy/smooth peanut butter, sweetened peach yogurt, and a bottle of spring water. Grain foods were purposely excluded from the breakfast to avoid any potential effects of sensory specific satiety (SSS). SSS is defined as the decline in the pleasantness of the sensory properties of a food that has just been eaten in contrast to foods that have not been eaten (34). Approximately 30 min after eating the SLB, participants were escorted to the Sensory Evaluation Laboratory and seated in semiprivate booths separated by partitions. Each booth contained a bottle of spring water, 2 napkins, and a pencil. Samples were presented in pairs (1 WG and 1 RG product) on a tray along with prelabeled questionnaires.

After the sensory evaluation, participants were escorted to a cognitive testing booth where they were seated in front of a desktop computer. Behavioral tasks based on the Leeds Food Preference Questionnaire (LFPQ), a validated tool for measuring explicit liking and implicit and explicit wanting (29), were administered using experiment generator software (Inquisit 3.0, Millisecond Software). The order of the tasks was randomly assigned across participants and counterbalanced across test days to prevent order effects. Photographic food stimuli (**Supplemental Figure 1**) were presented on a 17-inch flat screen monitor and measured 150 × 100 mm^2. Before each task, researchers read the on-screen instructions aloud and subsequently confirmed participants' understanding of the tasks. The investigator exited the cognitive testing booth to avoid biasing the participants' responses but remained in the general area in case a participant had any questions or concerns during the testing. Participants were told that the purpose of the computer tests was to gather information about their food preferences. Participants were released to go home after all testing was complete.

During the 6-wk intervention, participants were provided with a weekly market basket (MB) of assorted WG or RG grain products, approaching 100% of the DGA recommended total grain intake depending on calculated estimated energy requirements. Participants were instructed to record consumption of all grain products in a daily log booklet, including grain products not provided by the study. Instructions for accurate log entries included details about preparation methods, amount, location, and time of day the grain products were consumed. The provided grain products were preportioned to increase the ease and accuracy of recording in the log booklets. Recipe suggestions, measurement aids, and blank pages for notes were provided in the booklets. Participants returned all unused and prepared but uneaten products and all packaging materials along with the log booklet each week when they picked up their MB for the following week. Total servings of grain products consumed were calculated by measuring the disappearance of the provided foods and by analyzing data recorded in the log booklets. Participants were not required to consume all of the grain products provided each week and were not required to limit grain intake to only the products provided.

Weekly MBs

A variety of commercially produced and in-house prepared grain products were provided on a weekly basis to participants for 6 wk. Foods were weighed and packaged without brand identification or nutrition information by the Metabolic Kitchen and Human Feeding Lab in the WHNRC. Participants randomly assigned to the WG intervention received a weekly MB of WG products consisting of sliced bread, Wheaties breakfast cereal (General Mills, Inc.), cheddar-flavored Goldfish® crackers (Pepperich Farms), rice, couscous, penne pasta, spaghetti, tortillas, chocolate chip cookies, baking mix, and cornbread muffins. Participants in the RG intervention received closely matching RG versions of the same foods. Within each MB, grain products were packaged and labeled according to the instructions for home storage: room temperature (ready to eat), refrigerator, or freezer. Further details regarding the foods included in the MB have been reported previously (35). Participants were asked to incorporate the provided grain products into daily meals and snacks as they would with grain products they purchase for themselves. They were also instructed not to share their MB items with others. The total number of weekly grain servings for each participant was based on his or her daily energy needs that were estimated using the Harris Benedict equation (36) with anthropometric data gathered at the screening visit and a physical activity factor of 1.4.

Sensory evaluation

Sensory evaluation of the provided WG and corresponding RG products was conducted using standard sensory evaluation procedures (37). Sensory evaluation was performed on only 6 products from each MB group (WG and RG) as testing all of the provided grain products was deemed to have resulted in participant fatigue. The 6 sensory evaluation foods were sliced bread, Wheaties and cornflakes breakfast cereal, rice, Goldfish® crackers, chocolate chip cookie, and cornbread muffin. These product categories were chosen because they represent some of the most familiar and commonly consumed grain products in the United States (4, 38). Samples were identified to participants by a 3-digit code number and the name of the product category (e.g., rice) and served without any indication of brand, ingredients, nutritional content, or other descriptors. The order in which the food pairs were presented was randomly assigned for each participant, so everyone did not sample the same pair of foods first. The order of grain type sampled first (WG or RG) within each pair was randomly assigned within each testing session. Half of the subjects received the RG sample first and the WG sample second, and the other half of the participants were presented with the samples in the opposite order to prevent potential order effects. This order was reversed at the end-study testing. The sequential monadic presentation protocol was employed (39). Participants were instructed to first taste the sample on the left and answer all questionnaire items before tasting the sample on the right. Participants were instructed to taste as much of each sample needed to form an opinion and to cleanse their palate by rinsing their mouths with water before and after tasting each sample. There was no constant interstimulus interval imposed by the protocol (39). Participants indicated when they were finished with 1 pair of samples and after a 1-to-2-min rest, the next pair of samples was presented.

Participants rated the overall liking, flavor, texture, appearance, and familiarity of each product as well as their perceptions of its healthiness, the likelihood they would eat it again, and the anticipated amount they would need to eat for satiation (based on a pictorial representation of a portion). Using a 16-cm visual analogue scale (VAS) anchored at the left end by the descriptor "Not at all" and at the right end by "Extremely," participants responded to each question by drawing a vertical line through a horizontal line scale at the place that best corresponded to their opinion. In addition, space was provided after each question for participants to write comments clarifying their responses.

Explicit liking

The Single Foods Test was designed to assess hedonic liking of 20 foods varying in the dimensions of fat content and sweet taste. Photographic images of foods (Supplemental Figure 1) corresponding to the categories of high-fat sweet (HFSW), low-fat sweet (LFSW), high-fat savory (HFSA), and low-fat savory (LFSA) appeared one-by-one on the computer screen. The computer program randomly assigned the presentation order of the images. Participants were instructed to use the computer mouse to mark along an on-screen VAS positioned below the food image in response to the question, "How much do you like the taste of this food?" The 100-mm VAS was anchored at the left end by the descriptor "Not at all" and at the right end by "Extremely." When the participant clicked on the point of the line scale that best matched her/his opinion, the next image was generated. The test question remained onscreen for the duration of the task. Individual scores were averaged to create a score for each food category (possible range 0–100).

Implicit and explicit wanting

The Paired Foods Test, a forced-choice paradigm in which participants choose the food they most want to eat at that moment, was used to evaluate implicit and explicit wanting. Participants were instructed to hold their index fingers over the D and the L keys of the keyboard. The same food images used in the Single Foods Test representing the 4 food categories HFSW, LFSW, HFSA, and LFSA (Supplemental Figure 1) were presented in pairs side by side in the center of the computer screen. Participants were instructed to imagine having as much or as little of their desired food, but they had to choose which they wanted most out of each pair. If they preferred the food on the left side of the screen, they were to press the D key. If they would rather have the food on the right, they were to press the L key. Each key press generated the next pair of images. Participants were not informed that their reaction time was being measured, but they were instructed to respond as quickly and accurately as possible. The computer program was designed to randomly pair each food in one category with every food in the other categories for a total of 150 trials. Foods in each category were randomly presented on the left or right side of the screen to avoid potential bias due to handedness. Explicit wanting was operationalized as the relative preference or total number of choices for each food category (possible range 0–75). Implicit wanting was measured by the average response latency recorded in milliseconds for the choice of each food category, the premise being that the faster the reaction speed, the stronger the implicit wanting or motivation for that particular food category (40, 41).

Statistical analysis

All data were analyzed using SPSS version 22 (IBM SPSS) and JMP version 14.0.0. (SAS Institute Inc.). Post hoc analyses with Bonferroni correction for repeated comparisons were conducted to test for differences. Tests were 2 sided, and the significance level was set at $P < 0.05$. Independent samples t-tests were conducted to compare participant characteristics in the 2 groups at baseline and to compare average grain consumption between the 2 groups. Preliminary results suggested that sex might be an effect modifier, so sex was added to the models as a covariate. Results are presented as means ± SEs unless otherwise noted.

Consumption of grain products.

Total servings of provided grain products consumed were calculated by analyzing data recorded in the log booklets and verified by measuring the disappearance of the provided market basket foods. While the participants were instructed to record all grain products consumed, including those not provided by the study, the quality of the reporting of outside food was extremely inconsistent and deemed unreliable. The number of provided WG grain servings consumed during the intervention was compared with ≤1 serving WG/d baseline consumption using paired sample t-tests.

Sensory evaluation.

VAS scores for each of the 8 sensory evaluation questions were the dependent variables. Prior to analysis, the scores on the 16-cm VAS were recoded to a 10-point scale. The Shapiro–Wilk test of normality was conducted for each outcome variable. The responses for all sensory evaluation questions were not normally distributed, so a logit transformation was applied. A mixed-model ANOVA with a separate analysis for each question was used, with group, time, food type (WG or RG), and food as main effects. Interactions among group, time, food type, and food were also included in the model. The 8 questions were analyzed separately to provide information about the individual barriers or factors relating to preferred grain type. The model included 1 between-subject factor, group (WG compared with RG), and 3 within-subject factors, time (baseline compared with 6 wk), grain type (WG compared with RG), and food (6 foods).

Liking and wanting.

Responses were automatically saved in Inquisit and exported to Microsoft Excel for processing. Distribution of scores on the VAS from the Single Foods Test and the frequency and latency scores from the Paired Foods Test were assessed for a normal distribution and other assumptions required of parametric tests. Outliers in the VAS (liking) data, identified as scores on the VAS >3 SD from the mean (2 out of 352 data points), were excluded from analysis. Latency (implicit wanting) scores from the Paired Foods test required logarithmic transformation. Mixed-model ANOVA tests were conducted with time and food categories as within-subject factors, and group assignment as a between-subjects factor. Participants were included in the model as random effects. Percentage of grain products consumed was used as a covariate in the analyses.

Results

Recruitment

The CONSORT flowchart of participants in this study is shown in **Figure 1**. A total of 63 participants were enrolled. Of these participants, 8 withdrew before random assignment due to schedule changes or other personal reasons, leaving 55 participants to be randomly assigned into either the WG exposure or the RG control group. Eight participants dropped out of the WG group, citing time conflict, study burden, or family reasons. One person in each group was lost to follow-up with no reason given, leaving 45 participants to complete the intervention. After baseline, an independent statistical consultant set up the web-based random assignment process to assign participants to intervention (WG) or control (RG) groups by remote allocation using a permuted block size of 3. No one directly involved with participants had access to the allocation codes. Although the random assignment scheme was intended to result in a 2:1 ratio of WG to RG participants, partway through the recruitment process we noted that the distribution of taster status groups in our sample differed from the US distribution cited in the literature (42), resulting in a larger number of participants being allocated to the WG group than intended. At that point a new random assignment scheme disregarding taster status for subsequent participants in a 1:1 ratio of WG to RG was implemented in an attempt to increase the allocation to the RG group. However, early termination of the study

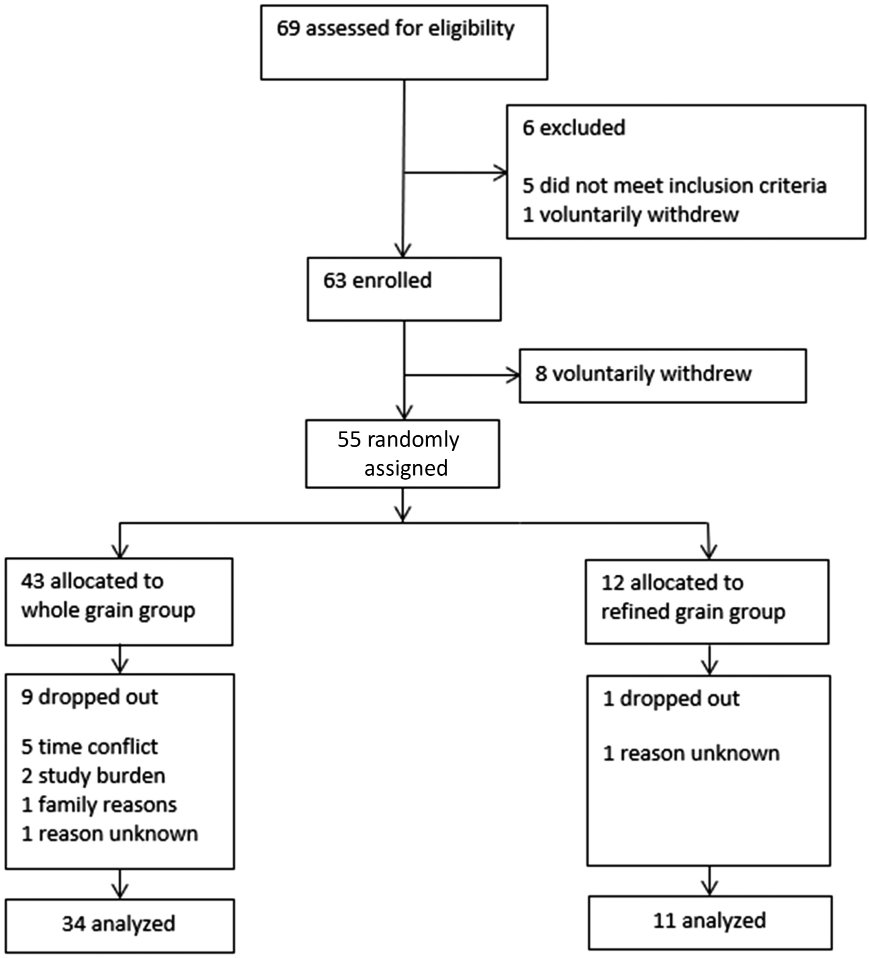

FIGURE 1 Flowchart of participants through the study.

for funding reasons in combination with the aforementioned random assignment issue resulted in an actual allocation of almost 4:1 WG to RG ratio. The final number of completers totaled 34 in the WG group and 11 in the RG group. Of the 45 participants who completed the study, liking and wanting computer data were available for only 43 participants due to equipment malfunction.

Participant characteristics

Baseline characteristics of the 45 participants (24 females) who completed the study are shown in **Table 1**. Independent samples *t*-tests revealed no significant differences in age ($P = 0.433$) or BMI ($P = 0.191$) between treatment groups.

Consumption of grain products

There were no significant differences in overall consumption between groups and no differences in consumption between week 1 and week 6 within or between groups. As previously reported, participants in the WG group consumed 47.9 ± 3.1% of the provided WG foods compared with 44.7 ± 7.8% of the RG foods consumed by the participants in the RG group (33). In terms of WG servings per day, 13 of 34 or 38% of participants increased their WG to ≥3 servings/d. In addition, 18 participants or 53% of the WG group increased their WG intake to 2–2.9 servings/d from baseline levels of ≤1 serving/d. Considering a baseline consumption of ≤1 serving of WG per day, WG consumption significantly increased ($P < 0.001$) in the WG group.

Sensory evaluation

Liking.

Overall liking is shown in **Figure 2**A for the RG group and Figure 2B for the WG group. There was a main effect of time on overall liking of sensory foods from baseline to week 6 ($P = 0.002$), with no difference

TABLE 1 Characteristics of participants

	Whole Grain (*n* = 34)	Refined Grain (*n* = 11)
Age, y	25.8 ± 6.2	24.2 ± 5.5
Sex, *n*		
Men	13	8
Women	21	3
BMI, kg/m^2	22.8 ± 2.9	25.6 ± 6.6
PROP status, *n*		
Nontaster	10	0
Medium taster	13	5
Supertaster	11	6

[1]Values are numbers of patients or means ± SDs.

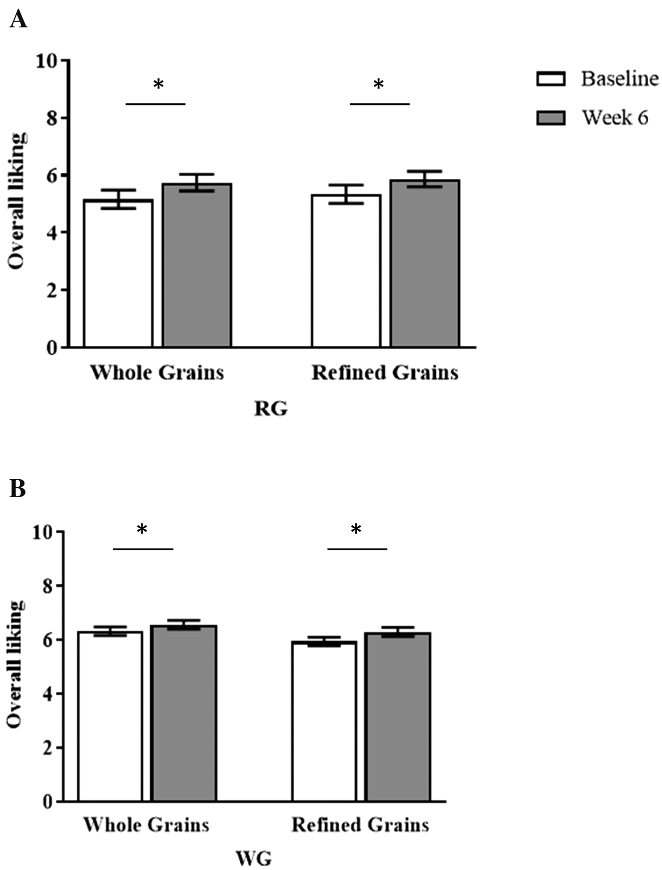

FIGURE 2 Overall liking scores for whole grain and refined grain sensory foods by the RG (A) and WG (B) groups. Participants in each intervention group tasted WG and RG versions of 6 of the foods provided in the market baskets. Liking scores for sensory foods increased from baseline to week 6. The magnitude of the change in liking scores was not different between grain types of sensory foods. Values are expressed as means ± SEs. *Significant difference from baseline measurements. RG, refined grain; WG, whole grain.

between treatment groups ($P = 0.672$). The increase in liking scores was also independent of grain type (WG or RG) of sensory foods. In other words, scores for both RG and WG sensory foods increased from baseline to week 6, and this increase was not different between those assigned the RG or the WG MB. Overall liking was greatest for the chocolate chip cookie followed by the Goldfish® cracker, sliced bread, breakfast cereal, cornbread muffin, and rice.

Appearance.
Ratings for appearance did not differ by group assignment or by sensory food grain type and did not change over time. Female participants rated sensory foods greater in appearance than did their male counterparts, independent of group assignment or grain type ($P = 0.020$). The differences in appearance ratings between male and female participants were greatest for rice, snack cracker, and sliced bread, the least sweet of the sensory foods ($P = 0.042$). A main effect of foods ($P < 0.001$) was evident, with the chocolate chip cookie and snack cracker being rated greatest in appearance, followed by the sliced bread and rice, and finally the breakfast cereal and cornbread muffin.

Flavor.
For sensory grain type interaction, participants in the WG group rated WG sensory foods greater in flavor than did participants in the RG group at both time points ($P = 0.042$). Scores for flavor of the RG sensory foods were not different between the WG and the RG groups. Scores for flavor of sensory foods overall (WG and RG) increased from baseline to week 6 in both the WG and RG groups ($P = 0.002$). Female participants rated sensory foods overall as greater in flavor than did the male participants ($P = 0.034$). Participants rated the chocolate chip cookies greatest in flavor, followed by the snack crackers, sliced bread, cornbread muffin, rice, and breakfast cereal.

Texture.
Participants in both the WG and the RG groups rated sensory foods greater in texture at the end of the intervention than at baseline ($P = 0.013$), with no significant differences between treatment groups or between grain type of sensory foods. Women's ratings of sensory foods were more positive for texture than men's ratings, with the largest differences seen in their scores for the snack cracker and rice ($P = 0.038$).

Familiarity.
Refined grain sensory foods were rated as more familiar than WG sensory foods in both groups ($P < 0.001$). Ratings of familiarity of RG sensory foods did not change over time in either group; however, ratings of familiarity of WG sensory foods by the WG group increased significantly from baseline to week 6 ($P = 0.009$). While RG versions of all the sensory foods were rated as more familiar than the WG counterparts, the differences were greatest for rice and smallest for the sliced bread ($P < 0.001$). Both men and women rated RG sensory foods as more familiar than WG sensory foods, but the difference noted by women was twice as great as that noted by men ($P = 0.012$).

Perceived healthiness.
WG sensory foods were perceived as being healthier than RG sensory foods by participants in both groups ($P < 0.001$), and this difference in perceived healthiness was greater in women than in men ($P = 0.032$). The WG and RG sensory foods rated to be most different in perceived healthiness between the women and men were the sliced bread, breakfast cereal, and rice, followed by the cornbread muffin, the chocolate chip cookie, and the snack cracker ($P < 0.001$). The WG and RG versions of the muffin, cookies, and crackers were more similar in appearance than other sensory foods; thus, the foods that were most obviously WG or RG were rated as most different in perceived healthiness.

Willing to include in the regular diet.
Participants in both the WG and RG groups were more willing to include both grain types of sensory foods in the diet at the end of the intervention than at baseline ($P = 0.049$) (**Figures 3**A and B). With the exception of WG rice, participants indicated being more willing to include WG versions of sensory foods over the RG versions ($P = 0.046$). Women indicated being more willing to include nonsweet foods (rice, sliced bread, snack cracker, and breakfast cereal) in the diet than men,

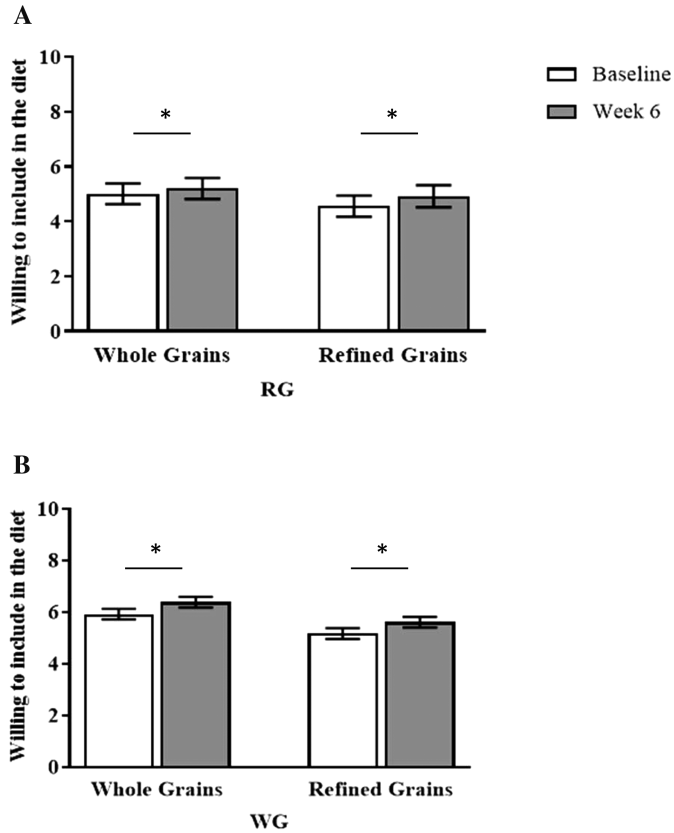

FIGURE 3 Willingness to include sensory foods in the regular diet (means ± SE) by the RG (A) and WG (B) groups. Participants in each intervention group tasted WG and RG versions of 6 of the foods provided in the market baskets. Participants in both market basket groups were more willing to include WG sensory foods in their diet at the end of the intervention than at baseline. *Significant difference from baseline measurements. RG, refined grain; WG, whole grain.

who indicated being more willing to include the sweet foods (chocolate chip cookies and cornbread muffin) ($P < 0.001$).

Explicit liking and wanting

In response to the question, "How much do you like the taste of this food?" there was a main effect of food category only, with LFSW foods being significantly less liked than the foods in the other categories ($P < 0.001$). Food categories ranked from most to least liked were as follows: HFSA > LFSA > HFSW > LFSW. Further analysis looking at high- compared with low-fat and sweet compared with savory showed that while HFSW and HFSA foods were equally liked, LFSA foods were liked more than LFSW foods ($P < 0.001$).

Overall, the frequencies of choice (relative preferences) of each of the 4 food categories were significantly different from each other ($P < 0.011$). The frequency of choice from the most to the least for each of the food categories was as follows: LFSA (49.8 ± 1.4) > HFSA (42.7 ± 1.1) > HFSW (35.2 ± 1.8) > LFSW (22.5 ± 1.4). Additionally, there was a group × time × food category interaction for relative preference ($P = 0.047$). Participants in the RG group chose sweet foods more frequently at week 6 than at baseline, along with a corresponding decrease in choice of savory foods, with the greatest changes seen in the HFSW and HFSA categories (**Figure 4**A). The WG group showed no changes in relative preference from baseline to 6 wk (Figure 4B).

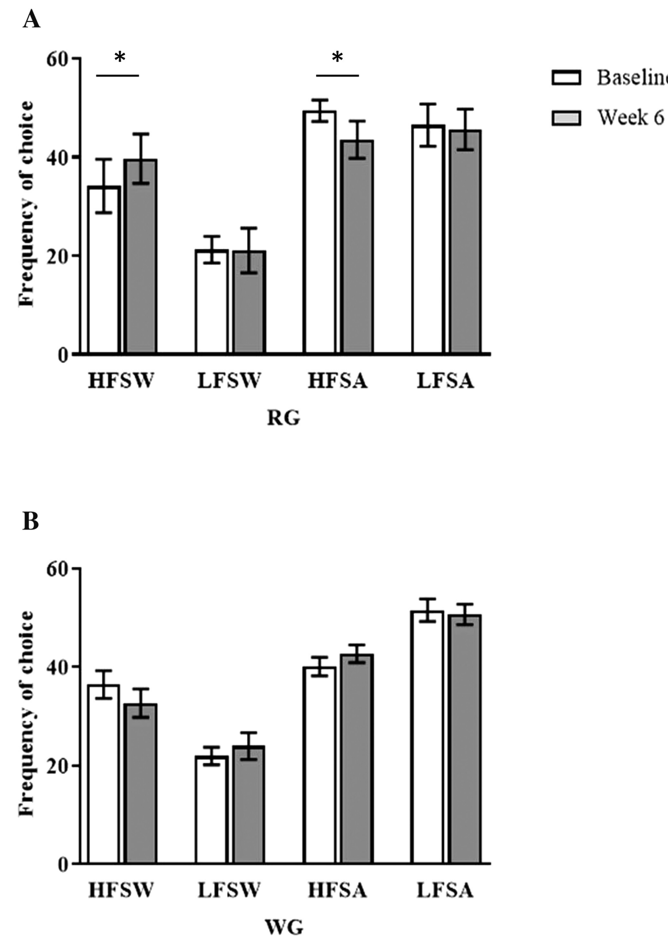

FIGURE 4 Explicit wanting (relative preference) by market basket group. Participants were shown pairs of food images presented side-by-side on a computer screen. The foods represented 4 sensory categories and participants were instructed to choose the food they most wanted out of each pair. Explicit wanting (relative preference) was measured as mean ± SE frequency of choice of foods in each of the categories. In the RG group (A), participants chose HFSW foods more frequently and HFSA foods less frequently at week 6 than at baseline. Frequency of choice for LFSW and LFSA did not change over time. In the WG group (B), participants chose HFSA and LFSA foods more frequently than HFSW and LFSW foods with no changes in relative preference over time. *Significant difference from baseline measurements. HFSA, high-fat savory; HFSW, high-fat sweet; LFSA, low-fat savory; LFSW, low-fat sweet; RG, refined grain; WG, whole grain.

Implicit wanting

Reaction time (RT) for choosing all 4 food categories decreased from baseline to postintervention ($P = 0.009$). Analysis revealed a main effect of food category ($P < 0.001$). RT for choosing LFSA foods was significantly faster than that for HFSW ($P = 0.001$) and LFSW foods

($P < 0.001$), but was not different for HFSA foods. RT for choosing HFSA foods was significantly faster than that for choosing HFSW ($P = 0.007$) and LFSW foods ($P < 0.001$). There was no difference in RT for choosing HFSW and LFSW foods. RT for choosing the savory-tasting foods was faster than that for the sweet-tasting foods independent of fat content ($P \leq 0.007$). Overall, RTs for the 4 food categories were as follows from fastest to slowest: LFSA (1136.3 ± 50.1 ms) < HFSA (1158.1 ± 52.1 ms) < HFSW (1285.9 ± 64.7 ms) < LFSW (1361.1 ± 67.5 ms).

Discussion

A 6-wk exposure to WG products in a free-living setting increased consumption of WG in self-reported low WG consumers. When WG foods were provided in amounts close to 100% of total grain recommendations, 90% of WG recipients at least doubled their WG consumption and 38% of WG recipients increased intake to DGA-recommended amounts. However, contrary to our hypothesis, repeated exposure to WG foods for 6 wk did not independently improve liking and acceptance of WGs. We found that the exposure effect was not specific to the type of grain products received or to the grain type of sensory foods tasted. A possible explanation for our findings is that the appearance of food provides expectations about its flavor and palatability (43, 44), and because the WG and RG versions of the sensory foods were nearly identical in size and shape, it is possible that visual cues primed ratings of overall liking and sensory perception to be similar for both types of grain products.

Increased familiarity scores for WG sensory foods by the WG group support participants' self-reports of habitual low WG consumption and indicate a positive effect of exposure to the provided MB foods. WG sensory foods were perceived as being healthier than the RG versions and, importantly, participants were more willing to include these foods in their regular diet at the end of the intervention. McMacken and colleagues conducted a series of focus groups to investigate consumer perception of WG foods as well as perceived barriers and facilitators to WG consumption (16). Lack of awareness of the health benefits of WG foods, the perception that healthy foods are not tasty, and the belief that a switch from RGs to WGs for health benefits could wait until an older age were among the cited barriers. Greater ratings of overall liking, flavor, texture, and familiarity seen at the end of the current study, in combination with greater perceived healthiness, likely contributed to participants' increased willingness to include WG foods in their regular diet.

We also sought to determine if exposure to WG foods would result in changes in explicit liking and explicit and implicit wanting for foods varying in dimensions of taste (sweet/savory) and fat content (high/low). This is the first study to use these computer paradigms before and after prolonged exposure to WG foods. In this sample we were unable to detect an effect of exposure to WGs on explicit liking or implicit and explicit wanting for foods representing HFSA, LFSA, HFSW, and LFSW categories. On the other hand, a 6-wk exposure to RG foods resulted in an increase in explicit wanting (relative preference) for HFSW and LFSW foods, suggesting reinforcement of sweet tasting foods regardless of fat content.

The sweet foods (low fat and to a lesser extent high fat) were the least liked by both groups at both time points. This finding may be explained by the provision of the SLB. The main purpose of the SLB was to ensure a controlled hunger state and to limit potentially confounding postingestive effects of widely varying types of breakfast foods. The only other criterion of the SLB was that it exclude grain products to avoid influencing responses in the sensory evaluation procedure that followed the breakfast. Because the SLB included apple slices and a fruit-flavored yogurt, it is possible that consumption of the SLB exerted a cross-modal SSS effect on liking scores for images of recognizably sweet foods. A similar cross-modal SSS effect was found by Finlayson and colleagues in a study in which the LFPQ was administered immediately before and after a test meal that included a high-fat savory food (pizza) (30). Results of the postmeal computer tests revealed that relative preference and implicit wanting (RT) decreased for savory foods and increased for sweet foods.

In the current study, faster reaction speeds for choosing the savory-compared with the sweet-tasting foods in the implicit wanting test were independent of group assignment and time point. Considering reaction speed, a proxy measure for implicit wanting, this finding indicates that savory foods were wanted more than sweet foods when participants were forced to choose between taste categories. It is possible that our SLB may have exerted a negative influence on implicit wanting for images of other recognizably sweet foods. However, shorter reaction times in both groups for choosing all food categories at week 6 suggest a potential learning effect of the tests rather than an increase in implicit wanting, although the extent to which a learning effect from a single test session exists after a 6-wk time interval is unknown. Future use of this measure could include a preintervention practice session to minimize potential learning effects.

Strengths of the current study include the use of sensory evaluation tests to directly measure liking and acceptability of grain products at the time of consumption. By assessing the individual hedonic aspects that contribute to overall liking, such as flavor, texture, and appearance, our results provide a detailed explanation of the aspects most important to these consumers in selection of grain products. The free-living nature of our intervention also provides a realistic picture of willingness and ability to incorporate study foods into the daily diet in our limited sample. Frequently cited barriers to WG consumption such as cost, availability, and ability to identify at the point of purchase were eliminated. This left only individual-level factors of taste and texture as potential barriers, both of which improved through mere exposure.

A limitation of this study was that the only means of assessing consumption of provided foods was through completion of the weekly log booklets and weighing back of returned MB foods, leaving data collection open to self-report bias. Future studies could be improved by the addition of a validated biomarker of WG consumption, such as plasma or urinary alkylresorcinols (45, 46). Other limitations included the overall small sample size and the unevenness of group sizes. The small number of participants in the RG group may have resulted in limited power to detect group differences. In addition, although we observed sex differences in responses to the sensory evaluation questions, we had no a priori hypothesis regarding sex differences and thus could only note those results. Further investigation of sex differences in sensory perception of foods is clearly warranted. Finally, the photographic food images used in our computer tests were created to closely match those used in the LFPQ (31), as that procedure has been validated in previous studies (31, 33, 41, 47). The only adjustment made was to replace foods commonly consumed by the British that are unfamiliar to Americans. Immediate recognizability is key in reaction time testing. Substituted foods were kept within the same food category, i.e., meal or snack item, and thus it seems unlikely that those few substitutions influenced these results.

In conclusion, provision of WG products improved perception of sensory attributes that contribute to liking and acceptability of WG. These results contribute to existing evidence that mere exposure can lead to increased acceptance and consumption of healthy foods, such as WG. The fact that consumption of provided grain products did not differ between RG and WG groups despite the fact that all were habitual low WG consumers demonstrates that replacing at least half of RG with WG is not only feasible but can be achieved with little effort. Switching from RG to WG represents one of the easier recommended dietary changes as consumers are not required to avoid specific foods but simply to replace RG with WG versions of the same familiar foods. Efforts to increase WG consumption may be most successful when focusing on enjoyment of taste over long-term health benefits.

Acknowledgments

The authors' responsibilities were as follows—NLK, ADL, DJB, WFH: designed research; ADL, BMR: conducted research; ADL: analyzed data and wrote the paper; NLK, SLC, BMR: critically revised the manuscript; ADL, SLC, NLK: had primary responsibility for final content; and all authors: read and approved the final manuscript.

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