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Methods and applications in eating behavior

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Methods and applications in eating behavior

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Editorial: Methods and applications in eating behavior

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Editorial on the Research Topic
Methods and applications in eating behavior

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One of the confines in the field of eating behaviors is the lack of methods and applications to investigate avenues for the promotion of health. This series aimed to highlight the latest experimental techniques and methods used to investigate fundamental questions in Eating Behavior. This Topic considered technologies, interventions, practices, and up-to-date methods which will help advance scientific inquiry in the field.

Fischera et al. proposed a design on the interaction of norms and identity to form a new protocol for identifying fruit and vegetable consumption. Descriptive norms influenced fruit intake intentions and vegetable intake when investigated for the interaction with the identification manipulation. Nève et al. validated a visually aided dietary assessment tool, and all macronutrients and total energy intake were satisfactory estimations to capture dietary habits in older adults. The research adds an easier estimation of dietary habits and macronutrient intake. Zahedi et al. proposed methods for the effects of posthypnotic suggestions (PHS) on food-related decisions. While the hypotheses and the methods are detailed in the manuscript, the second stage of the manuscript is currently being reviewed. Javaras et al. developed the Cyberball-Milkshake Task, a method to facilitate research investigating individual differences in the consumption of highly palatable food due to ostracism. Initial findings propose a method that can be developed in assessing real-world behavior, and potentially propose a more pragmatic method of assessing experimentally aversive experiences and eating behaviors. Devonport et al. examined the effectiveness of two brief interventions (i.e., daily diaries and mindful eating practice + implementation intentions) aimed to help individuals deal with food cravings and associated emotional experiences during COVID-19. While the two interventions did not differ between them, the change in cravings and emotional states were significant and add to the support during times of needing remote interventions. Scoffier-Meriaux and Paquet examined the hypothesis of a Zone of Optimal Regulation of Eating Attitudes in Sport, where a detailed account of matching disordered eating attitudes and self-regulation of eating attitudes proposes a purpose and utility in sports psychology. Pristyna et al. proposed behavioral change dependent on personality characteristics, where they investigated the association between Big Five Personality Traits and nutrition-related variables. Of special interest were conscientiousness, extraversion, and neuroticism, which were associated with obesity. Chen et al. proposed two plant-based dietary indices to assess the association with diabetes, hypertension, and related chronic diseases, leading to the proposal of the development of dietary strategies to prevent illness and promote health. Susta et al. conducted a study that aimed to identify the differences in brain activity in participants with anorexia nervosa (vs. healthy controls) using visual stimulus conditions combined with Brain Activation Sequences. The implications of this method are evident, where both diagnostic and prognostic value is added to the timely utility of treatments and psychotherapy. Deng et al. proposed the efficacy and mechanism underlying intermittent fasting combined with lipidomic in male rats. Six hours of time-restricted feeding provided evidence of improvements in metabolic-associated fatty liver disease.

The research in this collection represents globally diverse authorship, with longitudinal, experimental, cross-sectional, and secondary data of new and devised methods to assess eating behaviors. The applicability across cultures and the modification for specific populations remain elements that require further research and collaboration. The results of this Research Topic are projected to aggregate the way that we think of and investigate eating behaviors and add to the literature on promoting health behavior change.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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A special thank you to all editors and reviewers for their time and effort in putting this issue forward. Your efforts and hard work did support the authors in improving their manuscripts. Thank you to the authors, for the submissions and the collaborative spirit in enhancing the impact of your work. I am looking forward to future work that will derive as an outcome of this issue.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Validation of a Visually Aided Dietary Assessment Tool to Estimate Dietary Intake in an Adult Swiss Population

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Background: Accurately assessing dietary intake is crucial for understanding how diet affects a person's health. In large cohorts, paper-based dietary assessment tools (DAT) such as food recalls or food frequency questionnaires have emerged as valid tools with a low burden for participants.

Objective: To validate a visually aided DAT for use in studies with Swiss adults against the gold standard of a weighed 7-day food record (7 d-FR).

Design: Fifty-one adults (n = 24 women, n = 27 males) participated in the study and were recruited within two age groups (20–40 and 50–70 y). Each participant filled out the visually aided DAT, then the 7 d-FR. The DAT was compared to the 7 d-FR for total energy intake, macronutrients, sugar, water, and portions of fruits and vegetables. Pearson correlation and Bland–Altman analyses were used for statistical analyses.

Results: Total correlations ranged from 0.288 (sugar, $p < 0.05$) to 0.729 (water, $p < 0.01$). The older age group showed higher correlations for total energy intake, protein, fats, carbohydrates, and sugar, but not for water ($p < 0.05$). Correlations were moderate at $r > 0.5$, whereas only water and protein reached those values in the young group. Both groups overestimated total calories in kcal (+14.0%), grams of protein (+ 44.6%), fats (+36.3%), and portions of fruits and vegetables (+16.0%) but strongly underestimated sugar intake (−50.9%).

Conclusion: This DAT showed that all macronutrients and total energy intake were estimated more accurately by the older age group and therefore might be adequate to capture dietary habits in older Swiss adults.

Keywords: diet assessment tool, weighed food record, dietary intake, validation study, food frequency questionnaire

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INTRODUCTION

The assessment of dietary intake in adults is one of the key elements in risk stratification when assessing chronic diseases such as diabetes, cardiovascular diseases, or other lifestyle-related non-communicable diseases (1). Until now, there has been a trade-off between the accuracy of a dietary assessment method, its practicality, and its manageability in clinical trials (2). As such, in scientific settings, 24 h recalls and weighed food records (FR) as retrospective methods are most widely used (3). 24 h recalls aim to assess the food intake consumed in the 24 h before the assessment day. The main advantages and disadvantages of 24 h recalls have been well described (4). FR are most used during a 4- or 7-day period (4 d-FR/7 d-FR), where participants are asked to weigh and (or) report any food/drink item consumed during that time frame. This yields a precise overview of a person's food consumption, that may give information on dietary patterns during the week and (or) on weekend days. This prospective method, if properly conducted, counteracts a memory bias, which might occur in retrospective methods. However, FRs involve high effort by participants and evaluation of data by the study personnel can be burdensome because of high data volumes (5). Although the FR is considered the gold standard for dietary assessment, several disadvantages should be considered that have been described previously (6, 7). As a possible solution, food frequency questionnaires (FFQ) have emerged as more suitable options for large studies, making up for their lack of precision with their ease of use, the low burden for participants and study personnel, as well as the reduced costs when compared to other methods (3). Further, FFQs assess dietary habits retrospectively, meaning that these habits are not altered during the assessment period (8). Still, retrospectively assessing food intake may affect accuracy, and problems of underreporting or false reporting are recognized. In addition, each FFQ needs to be validated against the gold standard to ensure quality.

It has been extensively studied that study participants tend to answer questionnaires to fit social desirability (9–12). This means that behavioral patterns that are commonly seen as "good" or "healthy" (e.g., daily physical activity, being non-smoker) are overreported, whereas patterns and behaviors that are seen as "unhealthy" tend to be underreported (e.g., high consumption of sugary drinks).

In epidemiological studies, it is important to accurately capture nutritional habits such as daily sugar intake or fruit and vegetable consumption. The amount of fruits and vegetables consumed is important since an inverse association between fruit and especially vegetable consumption and the prevalence of metabolic syndrome has been reported in a meta-analysis (13–15). The World Health Organization (WHO) recommends a daily intake of five portions of fruits and vegetables or roughly 400 grams for adults (16). Conversely, the WHO recommends that sugar intake should be reduced to a maximum of 50 grams per day, as an increased intake of sugar is directly associated with the risk of obesity (13, 17). To date, one Swiss study has investigated the amount of total sugar intake (in adults) and found that participants consumed 107 grams of sugar per day on average (18). Although that study showed that sugar intake in Switzerland, as assessed *via* 24 h-recall, is lower than in other countries (e.g., Netherlands), it remains more than twice as high as the daily recommendations and Switzerland is listed as one of the European nations with the highest sugar consumption per capita (19, 20).

It was demonstrated that in many international studies, dietary habits (e.g., meal frequency, portion size, number of meals per day) differ greatly between younger and older adults (21–23). At the time of the present study, most validation studies of dietary assessment methods had been conducted in younger adults while the assessment tools are widely used in studies of elderly people. Such tools generally have moderate correlations (r-value 0.40–0.59) between the gold standard and the validated assessment tool. Other tools that have been developed specifically for older populations might not be suitable for younger participants (23–25).

The present validation study was part of the Cardiopulmonary Exercise Testing (COmPLETE) study, which tested over 600 healthy adults and 80 patients with heart failure (26).

In the present study, we validated a visually aided dietary assessment tool (DAT) against the gold standard, the 7 d-FR (27). Total energy intake (kilocalories, kcal), macronutrients (grams), as well as water (liters), fruits and vegetables (portions), and sugar intake (grams) were examined. We aimed to assess whether this tool is useful to provide a valid estimate of all macronutrients, as well as for fruits and vegetables, and daily sugar intake. Finally, the present study aims at validating the assessment tool for younger adults, as well as older adults equally.

MATERIALS AND METHODS

Study Population and Design

Study participants were recruited between March and May 2021 through advertisements *via* email, online flyers, and word of mouth in northwestern Switzerland. Eligible participants were 20–40 or 50–70 years of age (sampling stratified by age), and mentally and physically able to follow the study protocol. Exclusion criteria were as follow: illness during the study period that affected diet, substantial lifestyle changes during the study (e.g., smoking cessation, diets), and a cardiac pacemaker since the conducted study included bio-impedance measures for body composition between the first and second visit. Information about present chronic diseases (e.g., heart failure, cancer, diabetes) and the use of medication were collected *via* a telephone interview before the first visit. Additionally, smoking status was assessed before the start of the study. Participants received written information detailing the procedures of the study and they gave written informed consent before participation.

On the first visit, anthropometric measurements were taken, including body composition using the bio-impedance (InBody 720, InBody Co., Ltd., Seoul, South Korea). Then, blood pressure was measured twice after 10 min of rest with an automatic blood pressure monitor system (Omron Healthcare, Germany). Participants were asked to fill out the paper form DAT before they were instructed on how to complete the 7 d-FR. In addition, participants were asked not to change their dietary or physical activity habits during the monitoring period. The second visit occurred 7 or 8 days after the first visit and was identical to it. During the second visit, study personnel verfied that the study protocol was followed and discussed the results of the 7 d-FR with the participants. The sample size for the present study was determined according to a similar validation study from Switzerland (28). The present study was approved by the Ethics

Committee of Northwestern and Central Switzerland (EKNZ 2021-00406) and complied with the declaration of Helsinki.

Dietary Assessment

Dietary Assessment Tool

During the first and second visit, to assess habitual food consumption, participants reported which food items they consumed on a "typical day" using the DAT. A "typical day" was defined by the study personnel as a day, on which participants followed a routine they would follow on most weekdays (e.g., normal workday, illness-free). The DAT as used in the present study is provided in the **Supplementary Figure**. The DAT shows the food pyramid of the Swiss Society for Nutrition (SGE) (Version 2005 – 2011) on the left third of the page, a portion size equivalent for various food items of the respective category in the middle, as well as five mealtimes (breakfast, snack #1, lunch, snack #2, dinner) and a column for the sum of the five mealtimes. The food pyramid is divided into six levels, with several sub-levels, which are as follows:

1st section (top of the pyramid): Sweets (e.g., chocolate, cake, sweet beverages).

2nd section: *part 1*: vegetable oils, butter, nuts.

Part 2: fatty meals (e.g., sausages, fried food, cream sauces).

3rd section: *part 1*: Meats and meat-like products (e.g., chicken, fish, tofu, eggs).

Part 2: Dairy products (e.g., milk, yogurt, cheese).

4th section: Grains and legumes (e.g., bread, corn flakes, potatoes, pasta, lentils).

5th section: Vegetables and fruits, including fruit juices.

6th section (base of the pyramid): Unsweetened drinks (e.g., water, tea, coffee).

Underneath the pyramid: alcoholic beverages (e.g., beer, wine).

Seven-Day Food Record

Between the two visits (7–8 days apart), all participants were instructed to record their dietary intake over seven consecutive days. We used a modified version of the previously validated Freiburg Diet Protocol (29), which was developed by the German Federal Research Institute for Nutrition and Food. The FR was handed out in paper form. Participants were instructed to always keep the FR with them and to fill it out after each food or beverage consumption, irrespective of whether it was a meal or snack, to avoid lack of reporting. All participants received verbal and written instruction on how to keep track of their dietary intake and on how to use the DAT. Each page of the FR included additional written instructions. The FR had pre-defined food categories (e.g., bread, dairy products, legumes), with examples of foods for each category. The categories of the DAT and FR were similar but the FR had more subcategories and food items. Additional space was provided on the paper forms to allow recording of consumed foods not listed. All items were listed with the standard portion sizes, and participants were asked to report the number and size of portions consumed throughout the day or the amount (in grams or milliliters). For best precision, participants were asked to weigh all consumed food items using their own kitchen scale. Because of the COVID-19 pandemic restrictions during the study, restaurants, canteens, and bars were closed, and private gatherings were limited to five people, meaning that most – if not all – meals were consumed at home. This potentially positively affected the precision of the measurements since all participants were asked to weigh the food items with their own kitchen scale. Participants returned the completed 7 d-FR at the time of the second visit and they were able to discuss any issues they had encountered with the FR with the study personnel at that time.

All food items were entered into NutriGuide® Swiss (Version 4.9), an online software solution that calculates nutritional values of single food items, as well as for meals.

Statistical Analysis

After completion of data collection, all 7 d-FR were checked for plausibility and completeness by the study personnel.

Based on the food groups illustrated in the food pyramid of the DAT, all food items were categorized into sweets, fatty meals, fats, meat/meat-like products, dairy, grains, legumes, drinks, and alcohol. Each food group of the 7 d-FR was matched with the above-listed food group of the DAT. For the DAT, nutritional values in kcal of the portion size equivalents were calculated with NutriGuide® Swiss and multiplied with the number of portions consumed by the participant for each of the above-mentioned food groups. The total was calculated by summing all food groups. For the 7 d-FR, study personnel entered all food items into the NutriGuide® Swiss software, and nutritional values were calculated by averaging the caloric intake of the 7 days recorded.

Prior to data analysis, we tested for normal distribution of the data using the Shapiro–Wilk test and found that the data of both the DAT and 7 d-FR was positively skewed (p = 0.01 and p = 0.04, respectively) (30). The logarithmic transformation of the data showed no proportional bias (unstandardized β-coefficient = 0.106, p = 0.515). Therefore, all data are presented as median and interquartile range (**Table 1**). To calculate the differences between the medians reported in **Table 1**, we performed a quantile regression for unpaired samples.

Because the data was not normally distributed, all macronutrients, as well as total calorie intake, were logarithmically transformed (log10) for the analyses. Bland–Altman plots (**Figures 1–4**) were created for the log-transformed variables and transformed back to the original scale, as suggested by Euser et al. (31). The 95% limits of agreement for the Bland–Altman plots were calculated as the average difference ± 1.96 standard deviations of the difference (32). In accordance with Gerke (33), we created QQ-plots, histograms of the differences, and histograms of the results of the Preiss-Fisher procedure, which were all non-problematic (not reported) (33). The Bland–Altman plots were created for the entire population and not by age group, as the p-values of the log-transformed data of DAT – 7 d-FR were significant for both age groups. The correlation between macronutrients and water intake between the DAT and the 7 d-FR were calculated using Pearson's r (**Table 2**). To check for any abnormal weight changes, a paired-samples t-Test was run between groups for pre and post measurements. Statistical analyses were performed using SPSS (IBM SPSS version 27.0.

TABLE 1 | Energy intake by macronutrients and group.

Category		Total	20–40 years	50–70 years
			n = 27	*n* = 24
Energy (kcal)	DAT	2171 (1813–2514)	2253 (1955–3011)	1966 (1567–2431)**
	7 d-FR	1934 (1554–2241)	2122 (1702–2769)	1609 (1420–2158)**
	Difference (%)	12.3	6.2	22.2**
Protein (g)	DAT	111.5 (87.5–133.0)	118.2 (88.4–135.3)	109.0 (79.4–123.7)
	7 d-FR	76.4 (59.9–90.3)	80.2 (63.7–97.5)	70.6 (58.6–83.7)
	Difference (%)	45.9	47.4	54.4
Carbohydrates (g)	DAT	183.8 (136.8–248.2)	221.9 (179.3–278.8)	169.7 (111.3–207.6)**
	7 d-FR	206.5 (162.2–265.9)	241.2 (184.0–292.7)	184.6 (137.1–241.9)**
	Difference (%)	−11.0	−8.0	−8.1
Fats (g)	DAT	103.4 (89.2–126.3)	104.9 (90.4–134.8)	91.9 (87.0–122.9)
	7 d-FR	70.6 (58.0–96.1)	76.6 (59.6–115.3)	65.1 (53.1–79.7)
	Difference (%)	46.5	36.9	41.2
Sugar (g)	DAT	39.2 (31.1–54.2)	39.2 (34.1–56.0)	37.5 (27.1–50.7)
	7 d-FR	86.4 (59.4–124.4)	93.7 (66.3–133.4)	74.9 (52.2–116.3)*
	Difference (%)	−54.6	−58.2	−49.9
Fruits and vegetables (P)	DAT	3.0 (2.0–4.0)	3.0 (2.0–4.0)	2.5 (2.0–3.0)
	7 d-FR	2.0 (1.3–3.3)	2.0 (1.1–3.3)	2.1 (1.4–3.5)
	Difference (%)	50.0	50.0	19.0

*All values are displayed as Median (Interquartile Range) in kilocalories (kcal), grams (g), or portions (P) per day. Difference in percent is calculated as follows: (DAT/7 d-FR)*100.*
DAT, dietary assessment tool; 7 d-FR, Seven-day food record.
**Different from age group 20–40 years (p < 0.05).*
***Different from age group 20–40 years (p < 0.01).*

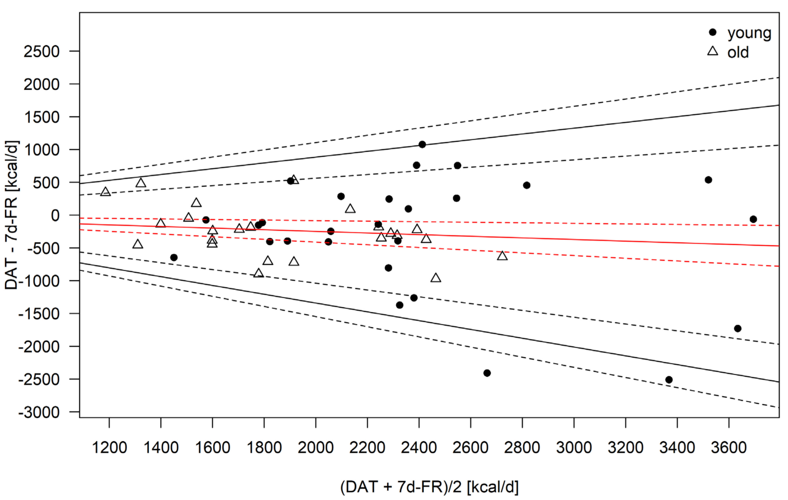

FIGURE 1 | Bland–Altman Plot of the total calorie intake as calculated from the 7-day food record (7 d-FR) and the visually aided dietary assessment tool (DAT). Legend: Red solid line, mean; black solid lines, 95% limits of agreement; dotted lines, 95% of the respective solid lines.

Armonk, NY, United States). All tests were performed two-sided and p-values < 0.05 were considered significant.

RESULTS

One subject did not follow the study protocol correctly and was excluded from the analyses; hence, 51 subjects were included. Participant characteristics are depicted in **Table 3**. The age range was 21–67 years, with an average age of 24.3 years in the young group and 57.4 years in the old group. There was a significant difference between the groups regarding height, body mass index (BMI), waist-to-hip ratio (WHR), and diastolic blood pressure. No statistically significant difference was observed for systolic blood pressure; however, it has to be noted that three participants of the older group were taking blood

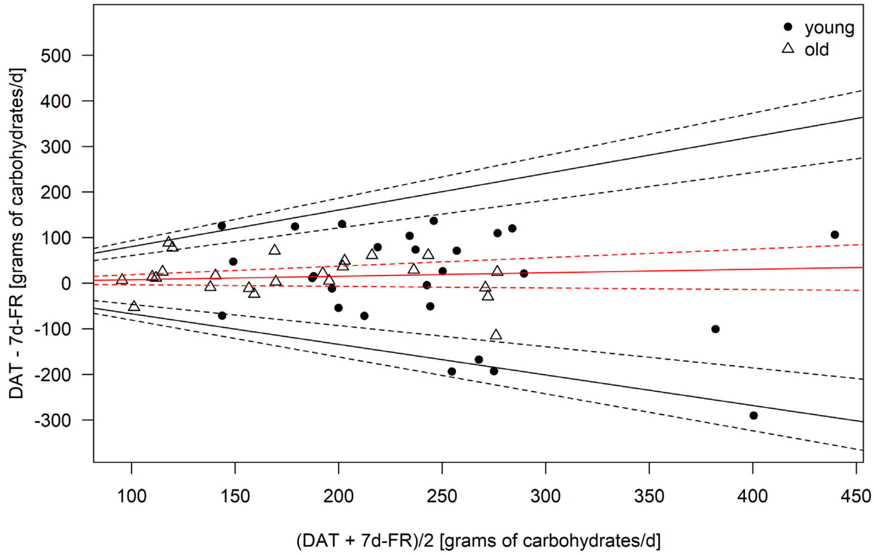

FIGURE 2 | Bland–Altman Plot of the carbohydrate intake as calculated from the 7 d-FR and the visually aided DAT. Legend: Red solid line, mean; black solid lines, 95% limits of agreement; dotted lines, 95% of the respective solid lines.

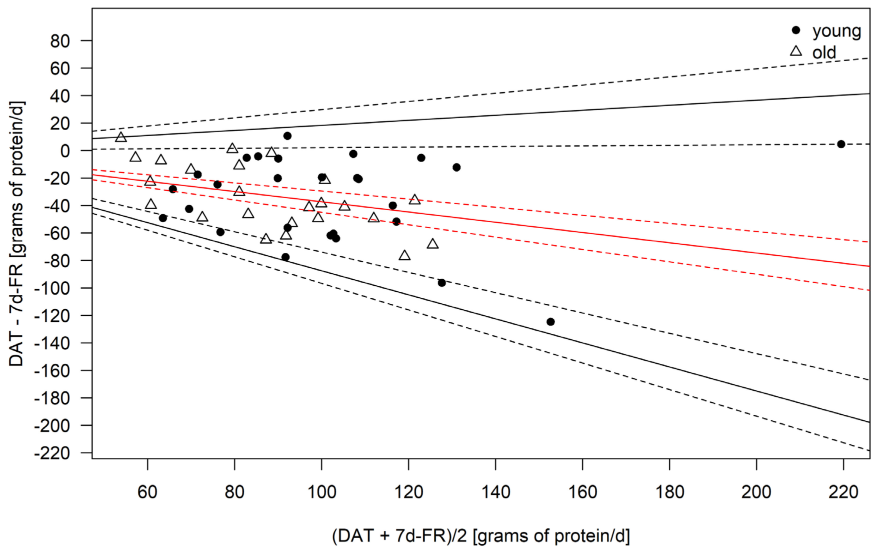

FIGURE 3 | Bland–Altman Plot of the protein intake as calculated from the 7 d-FR and the visually aided DAT. Legend: Red solid line, mean; black solid lines, 95% limits of agreement; dotted lines, 95% of the respective solid lines.

pressure-lowering medication. In addition, there was no significant weight change between the first and second visits in either group.

We found significant differences between the 20–40 and 50–70 groups with regard to total energy intake ($p < 0.01$) and grams of carbohydrates ($p = 0.03$) for the DAT and 7 d-FR (**Table 1**). Further, we found that subjects aged 50–70 estimated significantly lower sugar consumption using the 7 d-FR than subjects aged 20–40. The results of the present study (**Table 2**) display that this DAT shows a high correlation with the reference method in the older group. The highest correlation was found for total energy intake in the older group at 0.799, which was much higher than the young group (0.277, $p < 0.01$). However, although the correlation for total energy intake in the old group was higher than the young group, the mean difference between total energy intake in the young group was lower (13.5%) than the old group (14.7%). In addition to total energy intake, correlations between the DAT and the 7 d-FR were significantly higher in the old versus the young group for carbohydrates (0.776, vs. 0.228, $p < 0.01$), fats (0.494, $p < 0.05$ vs. 0.136, $p < 0.01$), and sugar (0.479, $p < 0.05$ vs. 0.184, $p < 0.01$). No significant differences were observed for the other variables.

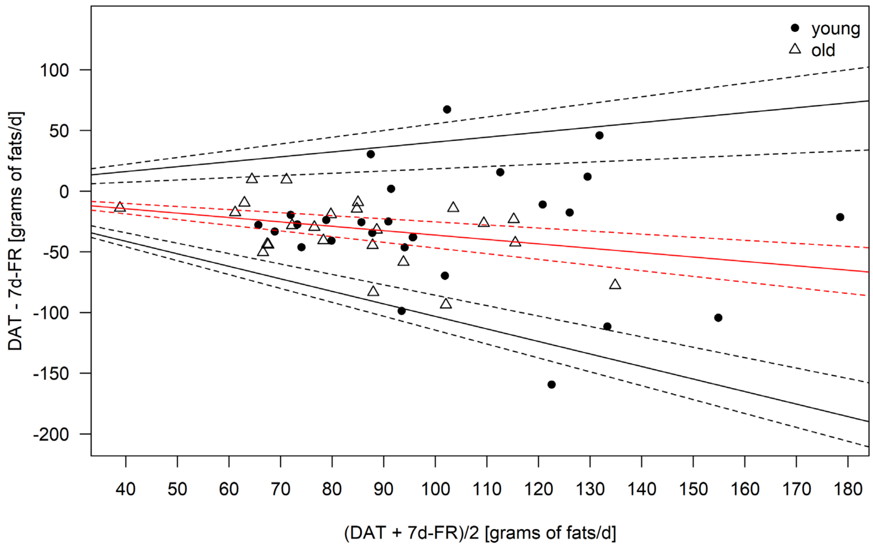

FIGURE 4 | Bland–Altman Plot of the fat intake as calculated from the 7 d-FR and the visually aided DAT. Legend: Red solid line, mean; black solid lines, 95% limits of agreement; dotted lines, 95% of the respective solid lines.

Regarding weight changes, we found that both groups were lighter at the second visit (0.3 kilograms in the young group, $p = 0.06$ and 0.2 kilograms in the old group, $p = 0.04$), with weight changes ranging from +1.7 to −2.1 kilograms. Only the weight change in the old group was significant ($p = 0.04$). No significant changes in lean body mass were seen in either group during the study (all $p \geq 0.2$). We found changes in fat mass in the young group ($p < 0.01$) but not the old group ($p = 0.375$). **Table 4** shows the mean bias, as well as upper and lower limits of agreement for the Bland–Altman plots. Due to the data being back transformed on the original scale, **Table 4** further shows the mean slopes, as well as the slopes for the upper and lower 95% limits of agreement for total energy intake and macronutrients.

The Bland–Altman plots are shown in **Figures 1–4**. Mean and 95% limits of agreement are displayed as solid lines, with the respective 95% confidence intervals displayed as dotted lines. As visible in and **Figures 1–4** and **Table 1**, the DAT appeared to overestimate total calorie intake, protein, and fat intake, whereas carbohydrates intake was underestimated. Bland–Altman analyses were not possible for fruit and vegetables intake, as they did not fulfill the necessary statistical criteria. In addition, all subjects in the old group were within the limits of agreement for all parameters. The difference between DAT and 7 d-FR was 237 kcal for total energy intake, 35.1 grams (144 kcal) for protein, 76.7 grams (314 kcal) for carbohydrates, 32.8 grams (295 kcal) for fats, and 47.2 grams (194 kcal) for sugar (**Table 1**).

TABLE 2 | Correlations between the DAT and 7 d-FR, by group.

Group	Kcal	Protein	Carbohydrates	Fats	Sugar	Water
Total	0.468	0.596**	0.483**	0.292**	0.288*	0.729**
20–40 years	0.277	0.584**	0.228	0.136	0.184	0.728**
50–70 years	0.799**	0.606**	0.776**	0.494*	0.479*	0.650**

Significant correlations ($p < 0.05$).
***Significant correlations ($p < 0.01$).*
DAT, dietary assessment tool; 7 d-FR, seven-day food record.

DISCUSSION

The present study aimed to assess whether the visually aided dietary assessment tool (DAT) is a valid instrument to estimate food intake in Swiss adults, aged 20–40 and 50–70 years. The gold standard 7 d-FR was used as a reference method and validity was investigated for all macronutrients (in grams), as well as total calorie consumption (in kilocalories), amount of portions of fruits and vegetables, and sugar intake (in grams). The age groups were defined in a manner to discriminate between

TABLE 3 | Characteristics of participants by age group.

	Total	20–40 years	50–70 years
Female, n (%)	51 (47.1)	27 (40.7)	24 (54.2)
Age *(years)*	39.9 (17.1)	24.3 (2.7)	57.4 (4.5)**
Height *(cm)*	174.6 (9.3)	177.4 (10.2)	171.5 (7.2)*
Weight pre *(kg)*	72.0 (13.8)	71.2 (14.8)	73.0 (13.0)
Weight post *(kg)*	71.8 (13.7)	70.9 (14.7)	72.8 (12.8)
LBM pre *(kg)*	30.9 (1.0)	32.8 (1.5)	28.9 (5.7)**
LBM post *(kg)*	30.9 (1.0)	32.6 (1.5)	28.9 (5.8)**
Fat mass pre *(kg)*	17.0 (9.2)	12.8 (8.1)	21.7 (8.0)**
Fat mass post *(kg)*	17.0 (9.3)	13.2 (8.2)	21.2 (8.8)**
BMI *(kg/m^2)*	23.5 (3.4)	22.4 (3.1)	24.7 (3.3)*

Data are mean (SD) unless stated otherwise.
**Different from age group 20–40 years ($p < 0.05$).*
***Different from age group 20–40 years ($p < 0.01$).*
BMI, body mass index; LBM, lean body mass.

young adults, who tend to have less regulated daily routines than older adults (23, 34). As demonstrated by Willet (3), FFQs are commonly used to assess long-term dietary habits, which was the key area of interest in the present study (3). We showed that the young group was able to estimate energy intake and all macronutrients more precisely than the old group. Across both groups, total energy intake, carbohydrates, and portions of fruits and vegetables were estimated more precisely than protein, fats, and sugar. However, correlations between the DAT and 7 d-FR were stronger in the old group, with significant correlations for total energy, protein, carbohydrates, fats, sugar, and water. The only significant correlations that were observed in the young group were for protein and water. Notably, the correlation of 0.799 for total energy intake in our old group was much higher than in comparable, recent studies (35, 36).

Our study reveals that the DAT we used overestimated total energy intake. This is in line with other European studies, that reported differences between the DAT and FR (37, 38). However, the recent systematic review by Sierra-Ruelas et al. (39) revealed that most DATs tend to underestimate total energy consumption. While the overestimation of energy in the overall population is acceptable (+12.3%), the Bland–Altman plots revealed that the DAT mostly overestimated fat and protein intakes, and that carbohydrates were underestimated. Since fats have an energy density of 9 kcal/g, an overestimation of fat consumption will inevitably affect the estimation of total energy intake. A potential explanation for the overestimation of fat intake in the DAT might be, that fats are highly represented in the DAT, making up a fast part of the upper section of the DAT. Further, the portion size of high-fat food items such as cheese or nuts is relatively high in the DAT, creating an overestimation of the consumption of high-fat foods. To our knowledge, we are the first to report back-transformed data in Bland–Altman plots for the validation of a DAT or FFQ. Therefore, we cannot precisely compare our results with other data. However, when comparing our findings with a similar validation study undertaken in Switzerland (28), we hereby show that the DAT we used appears to be more precise, especially in the older population which consumed less calories. However, no comparison can be made for the macronutrients.

Regarding the assessment of water consumption, there is no consensus on how to precisely assess intake (40). However, as stated in an overview by Mons et al. (41), food records should be preferred over retrospective methods because of higher precision. In our study, we were able to demonstrate that contrary to the current consensus, our method assessed water intake with high precision. In contrast, our study showed that sugar intake was poorly estimated with a correlation between the DAT and 7 d-FR of 0.184 (p = 0.40) and 0.479 ($p < 0.05$) in the young and old groups, respectively. Our population in the young group estimated a daily sugar intake of 50.6 (± 30.8) grams, which would be in accordance with the WHO recommendations. The old group estimated their sugar intake at 39.3 (±17.1) grams per day. However, the 7 d-FR showed that daily sugar intake was approximately twice as high (101.7 grams in the young and 81.6 grams in the old group) in both groups, indicating that sugar intake estimation was a challenge regardless of age. The intake measured in the 7 d-FR is in line with results published in 2019 on sugar consumption in Swiss adults (18). The authors found that in a population aged 18–75 years of age total daily sugar intake equaled 107 grams on average, which is comparable to our results of 92.2 grams (101.7 grams for the young group, 81.6 for the young group).

We found that both groups lost some weight during the study, on average 0.2 kilograms. It has been well documented that study subjects may change their dietary patterns to a healthier approach when being monitored to fit social desirability (7). However, as recently reported by Turicchi et al. (42), within-week weight fluctuations of up to 0.35% in body weight can be observed. This placed both of our groups within acceptable weight change ranges.

The present study has several limitations. Firstly, the assessment method using a visual aid with a colored pyramid is suggestive. Study subjects see which food items are more socially accepted, as they belong to the food category which has a "healthy" image. These categories are shown in green or blue colors, in contrast to yellow, brown, or red for food items that are regarded as less desirable. However, the food pyramid is well known in Switzerland and therefore all participants were familiar with it.

The portion size equivalents shown in the food pyramid and estimated by the SGE were relatively broad. For example, a portion of bread ranged from 75 to 125 grams, and the type of bread is not specified. Since older people generally consume smaller portions than younger adults, this may have led to an overestimation of the portion size in the old group, and an underestimation in the young group (34). Portion size estimation is considered one of the main reasons for inaccurate reporting in food questionnaires, and different portion sizes for various aged groups may be a valid solution (43).

Further, study personnel was present when participants filled out the DAT. Although study personnel was not actively watching the participants but rather performing other tasks, the presence of the personnel may have affected the estimations of the participants. In addition, the keyword "typical day" when assessing dietary habits was not defined using a specific period (e.g., last seven days, last month, or last year). While dietary intake may vary because of seasonality in some populations, an analysis using data from Swiss studies determined that seasonality decreased in the last decades and may not play a significant role today (44). A limitation of our analyses is that we did not define limits of agreement *a priori* based on biologically

TABLE 4 | Mean bias and limits of agreement (LoA) of the Bland–Altman plots for total energy intake and macronutrients.

Variable	Mean bias	LoA upper CI	LoA lower CI	Mean bias slope	LoA upper CI slope	LoA lower CI slope
Kcal	0.054	0.303	−0.195	−0.124	0.442	−0.671
Carbohydrates	−0.033	0.303	−0.369	0.077	0.803	−0.671
Protein	0.164	0.408	−0.080	−0.373	0.183	−0.875
Fats	0.159	0.496	−0.178	−0.362	0.404	−1.032

Legend: CI, 95% confidence intervals.

and analytically relevant criteria, as has been suggested for the Bland–Altman plot system by Giavarina (45). However, we are not aware of any validation studies with comparable dietary assessment methods (e.g., food frequency questionnaires), where the suggested approach has been applied and reported. Lastly, we determined our sample size according to previous studies but did not calculate the power for our analyses, therefore potentially not recruiting enough participants.

All participants used their private household scales since a standardized kitchen scale was not provided. No calibration of scales was therefore available. This may have led to discrepancies when weighing the food items and to systematic over-or underestimation of portion size. Therefore, energy intake as measured with the 7 d-FR can only be estimated.

We also did not monitor physical activity. Weight loss, as observed in our study, is the result of negative caloric balance. This is achieved either by lowering the total energy consumption or increasing physical activity and therefore energy requirements. It is possible that the old group did not achieve the weight loss through nutritional changes but rather by increasing physical activity. Lastly, the food pyramid that was used for the COmPLETE study and the present validation study was in use between 2005 and 2011. While there were no major changes in the pyramid since then, some trendy food (e.g., tofu, nuts, beans, lentils) may be underrepresented. The main strength of the present study was the use of the 7 d-FR, which is regarded as superior to retrospective assessment methods for this kind of validation study. In addition, most, if not all meals were consumed at home due to the restrictions of the COVID-19 pandemic. This may have led to more precise dietary monitoring during the study.

CONCLUSION

The present study showed that a simple dietary assessment tool can be used effectively in an adult Swiss population. The highest correlation between the DAT and the gold standard 7 d-FR was achieved in people aged 50–70 years old but younger, as well as older adults overestimated total energy, protein, fats, and fruits/vegetables portions. Sugar intake was strongly underestimated. To conclude, this DAT appears to be a valid alternative to the more complex weighed food records in epidemiological studies to estimate dietary habits but not to calculate precise macronutrients intake.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Swiss National Science Foundation (SNSF) grant no. 182815. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AS-T and GN were responsible for conceptualization and methodology. GN, LB, and LL were in charge of recruitment and conducting the research. GN performed the statistical analyses, and wrote the manuscript. CH, CB, and NS provided expert advice for statistical analysis and manuscript review. AS-T was responsible for funding acquisition. All authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2022.844156/full#supplementary-material

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The Nature and Persistence of Posthypnotic Suggestions' Effects on Food Preferences: An Online Study

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Food preferences are crucial for diet-related decisions, which substantially impact individual health and global climate. However, the persistence of unfavorable food preferences is a significant obstacle to changing eating behavior. Here we explored the effects of posthypnotic suggestions (PHS) on food-related decisions by measuring food choices, subjective ratings, and indifference points. In Session 1, demographic data and hypnotic susceptibility of participants were assessed. In Session 2, following hypnosis induction, PHS aiming to increase the desirability of healthy food was delivered. Afterward, a task set was administrated twice, once when PHS was activated and once deactivated. The order of PHS activation was counterbalanced across participants. The task set included a liking-rating task for 170 pictures of different food items, followed by an online supermarket where participants were instructed to select enough food for a fictitious week of quarantining from the same item pool. After 1 week, Session 3 repeated Session 2 without hypnosis induction in order to assess the persistence of PHS. The crucial dependent measures were food choices, subjective ratings, and the indifference points as a function of time and PHS condition.

Keywords: eating behavior, food choice, food preferences, hypnosis, online-supermarket, posthypnotic suggestions

INTRODUCTION

The increasingly obesogenic prevalent diets (1, 2) in modern society (e.g., high in sugar or salt, high-fat red meat, ultra-processed food, "junk food") are posing threats to human health, biodiversity, and the climate. Therefore, there is an urgent need to shift toward more healthy diets [e.g., (3)]. The rampant obesity epidemic demonstrates that traditional efforts toward diet change are insufficient (4–7). Therefore, it is crucial to seek new ways to strengthen healthy food choices. Notably, food choices are subject to several interacting factors: food preferences, impulsive reactions, and cognitive control (8–11). Often, good intentions to eat healthy food disintegrate under the force of competing preferences or impulsive behavior. The traditional approach to diet regulations focuses mainly on unhealthy food restrictions through strengthening cognitive control, which showed limited success at best [for review, see (12, 13)]. In the present study, we explore the utility of posthypnotic suggestions (PHS) in biasing food preferences in favor of a healthier diet.

Improving diet habits, which are formed already during sensitive periods early in life (14, 15), requires increasing the preference for and desirability of healthy food on an affective level (16). The acquisition and modulation of food preferences and eating habits involve congenital factors, exposure (17), and a multitude of cognitive (13), affective (16), social, and cultural influences (18) that no single intervention can shoulder. However, PHSs can integrate cognitive and psychosocial factors and successfully change implicit food preferences toward more healthy options (16, 19). Nevertheless, previous efforts were (1) mainly focused on food preferences and not on actual food choices, (2) did not investigate the persistence of the effects, and (3) only recruited participants who were at least moderately responsive to hypnotic suggestions. These issues are addressed in the present study.

To better estimate the effects of PHSs in real-life-like situations, we utilized (I) an online shopping mockup that included a large number of food items and (II) also measured subjective values for the same items. By measuring both subjective values and food choices, we were able to calculate indifference points of food items. Indifference points in binary choices refer to positions where agents might accept or reject an item with a similar probability (20, 21), which can be used to shed light on the underlying cognitive mechanisms of choice behavior. Additionally, in order to address whether the effects persist over time, we re-tested the effects of PHSs after 1 week. Finally, to assess the generalizability of the previous results (16), we recruited participants regardless of their responsiveness to hypnotic suggestions.

Hypothesis

Together, food choices, preferences, and indifference points can be used to elucidate the mechanisms underlying PHS effects. If choices and preferences for low-calorie food items are increased in the PHS-activated compared to the PHS-deactivated condition, but indifference points are unaffected, one can conclude that PHS modulates choices by affecting explicit preferences. On the other hand, if choices of low-calorie food items are increased, but preferences are not, then a decrease in indifference point may indicate that PHS affects implicit food preferences that are not explicitly accessible. Finally, the increase in preferences without any modulation of choices, but accompanied by increased indifference points for low-calorie items, will indicate that PHS can only affect explicit preferences that are insufficient for affecting choices.

Concerning high-calorie food items, if preferences and choices are decreased, stable indifference points indicate that PHS modulates choices though affecting explicit food preferences. In contrast, if choices of high-calorie food items are reduced but not preferences, an increase in indifference points should be expected. This can be interpreted as related to an increased contribution of top-down cognitive control in food choices. Notably, for high-calorie food items, we do not expect a decrease in preferences that is not accompanied by decreased choices.

Furthermore, we expect the PHS effects on food choice and food preferences to be stable across sessions. Finally, we expected that in both sessions, participants' hypnotizability would be correlated with the observed behavioral effects.

METHODS

Sample Size and Inclusion Criteria

About 40 participants would be recruited *via* different media. The sample size was chosen based on a priori power analysis with $\alpha < 0.05$, $1 - \beta > 0.95$, $\eta_p^2 > 0.08$. The critical values are determined based on the suggestion of Cohen (22), and the effect size is estimated based on previous results [e.g., (16)]. Notably, Zahedi et al. (16) found a medium effect size of $\eta_p^2 = 0.22$. However, since only medium- and high-hypnotizable participants were included in that sample, we adjusted the expected effect size for the current study from medium, i.e., $\eta_p^2 = 0.22$, to small, i.e., $\eta_p^2 = 0.08$. This adjustment is crucial as in the current study, participants are included regardless of their hypnotizability scores, and therefore, we will also have low- in addition to medium- and high-hypnotizable participants.

After first contact, we excluded underweight (BMI < 18) and obese (BMI > 30) individuals and anyone with a history of psychological or neurological problems. Individuals outside of the acceptable BMI range would be informed about the reasons for their exclusion and the recommended range of healthy body weight (i.e., BMI = 18–30) and are advised to consider contacting their physician. The study was approved by the ethics committee of the Institut für Psychologie of the Humboldt Universität zu Berlin (approval number 2021-36). Prior to the experiment, informed consent is obtained according to the declaration of Helsinki, and participation is compensated by money (i.e., 10 euro/h) or course credit. The study is conducted fully online.

Materials and Tasks

The hypnotizability of participants is measured by the German version (23) of the Harvard group scale of hypnotic susceptibility—form A [HGSHS: A (24)]. In HGSHS: A, 12 different suggestions are delivered to participants, and their responsiveness is determined based on the number of items to which they could objectively (based on a self-report questionnaire) respond. Each participant can achieve a score between 0 and 12 according to the scoring procedure suggested by Kihlstrom and Register (25).

Other materials consisted of the Edinburgh Handedness Questionnaire (26), the German Nutrition Knowledge Questionnaire (NKQ) (27), and the Self-Regulation of Eating Behavior Questionnaire (SREBQ) (28). The NKQ consists of 22 questions about the knowledge of healthy food choices and the sources of nutrients in food. The SREBQ consists of four questions aiming to evaluate an individual's capacity for regulating eating behavior.

The online supermarket (**Figure 1**) was organized based on eight food categories, including 170 products in total. The items were inspired by existing online shops in Germany aiming to simulate near-real life food shopping behavior. For instance, a

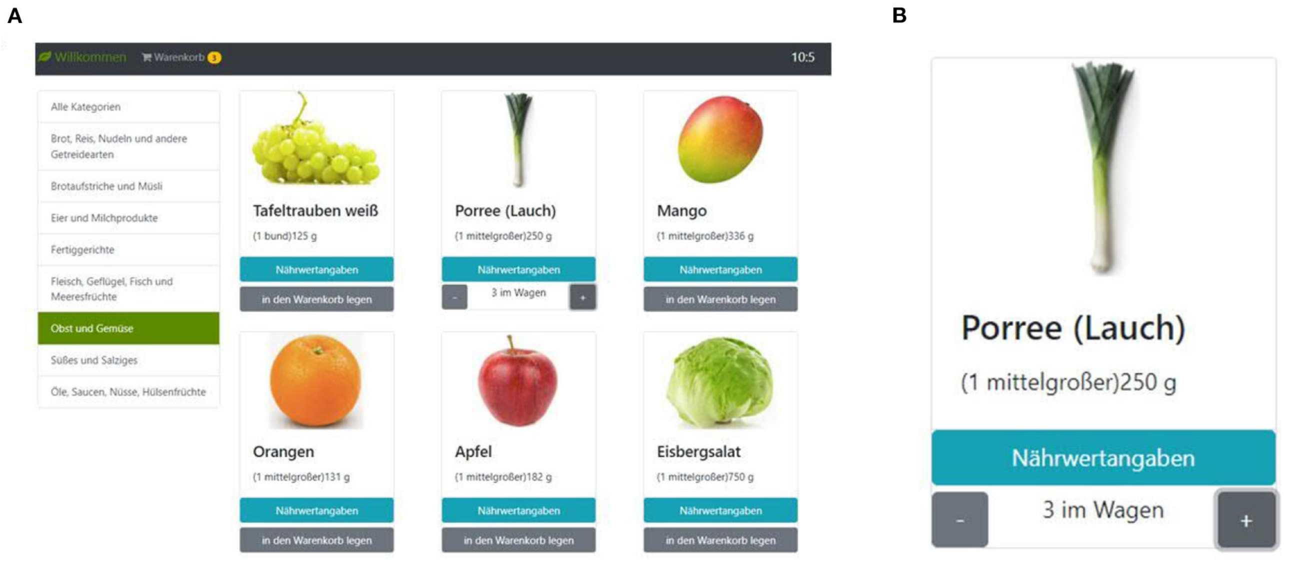

FIGURE 1 | The screenshot of the supermarket task. **(A)** Participants can choose different food categories shown on the left side to see their items. On the top right corner, the remaining shopping time is presented, and on the left top corner, they can see their shopping basket and modify its content. **(B)** For each object, participants can see the nutritional values and select how many they wish to put in their basket.

diverse array of options was presented for each product (i.e., full-fat milk and low-fat milk) to enable participants to choose their preferred items.

The eight categories of food items in the supermarket are as follows:

1: Bread, rice, pasta, and other grain products (e.g., toast bread, pretzel, croissant, etc.),
2: Bread spreads and breakfast cereals (e.g., honey, jams, chocolate creams),
3: Eggs and dairy (e.g., milk, cheese, yogurt),
4: Convenience foods (e.g., filled pasta, pizza, potato salad),
5: Meat, poultry, fish, seafood (e.g., salami, minced meat, smoked salmon),
6: Fruits and vegetables (e.g., tomato, onion, pepper),
7: Sweets and salty snacks (e.g., chocolate, candy, ice cream),
8: Oils, sauces, nuts, legumes (e.g., olive oil, cashew nuts, ketchup).

After choosing a category, between 16 and 26 images per category are shown. For each item, its name is shown above the image; further, the nutrition facts of each item can be inspected by clicking a corresponding button on the screen. For each item, the package size is relatively small to be equal to approximately one average serving size; for example, participants can choose to buy a single egg or a single potato. However, there is no limit to the number of a given item that can be placed in the shopping basket. Each item can be placed in the shopping basket by pressing a corresponding button on the screen. Also, participants can directly select a specific number (i.e., $1 < n < 20$) of each item. The shopping basket can be inspected as well, and the number of items can be corrected before making the final decision. The online supermarket is conducted with the instructions that participants should imagine that they have to quarantine for ∼1 week. They should order all food they want to consume during this period from the online supermarket. They have no budget limit and can choose as many products as desired. The only restriction is that the time limit for the online supermarket task is 15 min in total. We did not introduce budgetary restrictions into the online supermarket task because it might interact with or even overshadow the effects of participants' preferences on their food choices [e.g., (29–31)]. This question, however, might be tackled in subsequent research after demonstrating that PHS can indeed affect food choices.

In the food preference rating task, participants are shown all the food items offered in the supermarket task in randomized order. Participants are to rate each item for how much they like it and independent of whether they want it at the moment. Ratings are performed on a Likert scale from 1 (Don't like it at all) to 7 (Like it very much). There is a response window of 5 s for each item, after which the trial is considered a miss. The food preference rating task requires about 10 min.

Procedure

The experiment is conducted online *via* Zoom (or a similar) platform and involves three sessions. All questionnaires are implemented through the SoSci Survey platform (Version 3.0. 01, www.soscisurvey.de), and the individualized links are sent to participants in real-time during each session. In Session 1, written informed consent is obtained, and demographic information (age, sex, height, weight, educational background), NKQ, and SREBQ are collected. Afterward, the German version of HGSHS: A is administered in order to determine the hypnotic susceptibility of participants. We do not exclude any participants based on the screening results. Instead, susceptibility scores were used as a regressor in other analyses. Session 1 takes about 2 h and is conducted as an online group session (with up to five participants).

About 1 week after Session 1, Session 2 is conducted, lasting about 2 h. In Sessions 2 and 3, each participant is tested individually. Session 2 starts with hypnosis that includes a PHS aiming to induce a strong desire for healthy food. The hypnosis procedure and the employed PHS are the same as in Zahedi et al. (16). Next, the food preference rating and the online supermarket are conducted twice, once with the posthypnotic suggestion activated and once deactivated. The order of conditions (i.e., posthypnotic suggestion activated and deactivated) will be counterbalanced across participants.

Session 3, following between 3 and 10 days after Session 2, is identical in its procedure to Session 2, except that hypnosis is not applied again. The order of PHS activation and deactivation for each participant is the same as in Session 2. The interval between Session 2 and Session 3 appears to be justified considering the effects of PHS in other contexts. For instance, Böhmer and Schmidt (32) have shown that a safety-promoting PHS was effective even over several weeks (Median = 49 days, Range = 7–169 days) after the hypnosis induction.

Data Analysis

Based on our previous results (16), we expect that posthypnotic suggestions will increase subjective preferences for healthy low-calorie food items and decrease the subjective preferences for unhealthy high-calorie food items without affecting indifference points of these items. That means participants choose what they want based on the same principles as before, and therefore, their indifference points are unaltered. However, their preferences for healthy food items are increased, and hence, they choose healthier options. Following Clark et al. (33), we categorize as low-calorie healthy items: (1) vegetables, (2) fruits, (3) legumes, and (4) fish and marine products. Unhealthy food items were: (1) red meat, (2) processed and ultra-processed food, and (3) sugary and salty snacks. All remaining food items are categorized as neutral. By conducting general linear modeling, we investigate whether the posthypnotic suggestion condition and its interaction with food categories and time affected either subjective food preferences, as measured by the food rating task, or food choices, as measured by the shopping task.

In each model, the PHS condition (PHS-activated vs. PHS-deactivated), Session (Session 2 vs. Session 3), Healthiness (healthy, neutral, and unhealthy food items), and the interaction between these factors are included as fixed effects. Further, a random intercept for the participants and a random slope for their hypnotizability will be assumed (Equation 1). A model with only a intercept will be compared to the full model described above to gauge whether each factor contributes significantly to the results.

$$Outcome \sim PHS * Healthiness * Session + \left(1 + Hypnotizability \middle| Subjects\right) \quad (1)$$

Further, if any significant behavioral result was observed, we will test the point-biserial correlation between the observed effects and hypnotizability scores.

The results from the food rating and the online supermarket tasks are used to calculate indifference points (20, 21) for all food categories with sufficient responses and per posthypnotic suggestion condition and session. In the shopping task, chosen and non-chosen items are designated as 1 and 0, respectively. Indifference points are calculated using logistic regression modeling. For each participant in each condition, choices were entered into the model as a binary input (i.e., yes = 1, no = 0) and subjective ratings as continuous predictors. The output of the model represents the probability of choosing an item giving the subjective rating for that item:

$$p_{j,i,k}(Y) = \frac{1}{1 + \exp^{(\beta_0 + \beta_1 x)}} \quad (2)$$

Where x designates subjective rating, Y choice, j participant number, i session (e.g., pre-training), k calorie content (e.g., low-calorie), and β_0 and β_1 are model parameters. Then for each of the remaining participants at each condition, the indifference points are defined as the subjective rating that predicts choosing an item with the probability of 50%. The indifference points are analyzed with the same approach used for assessing subjective ratings and food choices.

Exploratory Analyses

In exploratory analyses, we will investigate the correlations between observed effects and NKQ and SREBQ results. Further, as macronutrients (e.g., proteins, carbohydrates, and fats) can affect health and cognition [for review, see (34)], we extracted the macronutrients information of the items in the shopping baskets for each condition and session. First, we assess whether the PHS condition affected the macronutrients balance. Finally, the amounts of macronutrients coming from different food categories are calculated to assess the effects of PHS and time.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the Department of Psychology of the Humboldt-University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AB: methods development. AZ: conceptualization, design, manuscript writing, methodology, and data analysis. JL and RÖA: data acquisition, data analysis, and manuscript writing. WS: conceptualization, design, and manuscript writing. All authors contributed to the article and approved the submitted version.

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A Social Norms and Identity Approach to Increasing Fruit and Vegetable Intake of Undergraduate Students in the United Kingdom

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This study investigated the influence of descriptive norm messages that either communicated that university students eat a sufficient amount of fruit and vegetable (F&V) or that they do not, on F&V consumption, and whether or not any effects are moderated by student identification. An online 2 (Norm: "Sufficient"/"Insufficient") × 2 (Identification: "Low"/"High") experimental design was employed. Infographics containing "sufficient"/"insufficient" F&V intake descriptive norms were presented. An identification manipulation was employed to create "high"/"low" student identifiers. F&V intake intentions were assessed after the manipulations; self-reported F&V intake was reported at 2 days post-intervention. Undergraduate students in the United Kingdom ($N = 180$) reported their intake intentions, of which 112 (62%) completed the behavioral follow-up. Participants were predominantly white female students from Scottish universities, mean age 20.4 (±1.6) years. Baseline mean F&V consumption was high (4.5 ± 2.8). There were no significant main effects of Norm or Identification manipulations on F&V intentions and intake. Significant norm × identification interactions were revealed for fruit intake intentions and vegetable intake at follow-up, indicating half-portion differences (~40 g) between groups. Ironic effects were observed for "high" identifiers, who neither intended to, nor acted in accordance with group norms; "low" student identifiers intended to and followed group norms, whereby the "sufficient"/"low" group intended to consume significantly more fruit portions and consumed more vegetables than the "insufficient"/"low" group. Given the half-portion differences between groups resulting from the norm × identification interactions, future research on a larger sample of young adults with low F&V intake is warranted to further explore the conditions under which moderating effects of identification are observed and the underlying mechanisms.

Keywords: social norms, descriptive norm, fruit, vegetable, identification, eating behavior

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INTRODUCTION

A robust association exists between fruit and vegetable (F&V) consumption and reduction in all-cause mortality and in the occurrence of several chronic diseases such as cancer and cardiovascular disease (Wang et al., 2014; Aune et al., 2017). The United Kingdom (National Health Service (NHS), 2018) recommends that adults (≥18 years old) should consume at least five portions (5×80g) of F&V daily. Despite the introduction of the national "5-a-day" campaign (National Health Service, 2018), the latest surveys show national consumption of F&V falls short of the recommended amount (Rose, 2018; NHS Digital, 2019). The age cohort who consume the least F&V are young adults (16–24 years), who, in England, consume approximately 3.3 portions daily (NHS Digital, 2019), while intake by their Scottish counterparts is lower at 3.2 portions daily (Rose, 2018).

Young adults' low F&V consumption is concerning as it is the period in which eating habits begin to form, after which resistance to change of established habits increases with age (Gall et al., 2000; Lien et al., 2001). Young adults' eating behavior is predominantly influenced by peers (Stok et al., 2015; König et al., 2017). Therefore, harnessing social influences may be an effective approach to improving F&V intake (Higgs and Thomas, 2016; Stok et al., 2016).

Social norms are defined as behavioral standards that indicate appropriate and correct behavior (Aronson et al., 1998) and can be used in models as determinants of intentions and behavior. For example, the Theory of Planned Behavior (TPB; Ajzen, 1991) posits that intentions are determined by one's attitudes, perceived behavioral control, and subjective norms (i.e., one's norm perceptions) and predicts subsequent behavior from intentions (Ajzen and Madden, 1986). Norms may reflect what the group should be doing, i.e., perceived approval about a behavior (injunctive norms) or what the group is actually doing, i.e., perceived behavior (descriptive norms; Cialdini et al., 1990). Exposure to descriptive norm messages has been found consistently to alter eating behaviors in field experiments (Mollen et al., 2013; Thomas et al., 2017), experimental laboratory studies (Stok et al., 2012, 2014b), systematic reviews, and meta-analyses (Robinson et al., 2014b; Stok et al., 2016 for reviews). Recent research also indicates that descriptive norms are often more successful in increasing F&V intake than conventional messages highlighting the health implications of consuming sufficient F&V (Croker et al., 2009; Mollen et al., 2013; Robinson et al., 2014a).

Prior studies have used non-norm-based messages as a comparator to descriptive norm-based messages. However, de Bruijn et al. (2015) argue that such control messages lack validity. When it comes to "real-life" normative content, it is norms regarding unhealthy behavior—problem behavior—that are most frequently conveyed by mass media and health campaigns (Schultz et al., 2007; Stok et al., 2012; Niederdeppe et al., 2014). de Bruijn et al. (2015) have investigated whether desired descriptive norms were effective when compared with undesired or "problem" descriptive norms on eating intentions (fruit) and behavior, but this small study focused on older adults who may be less sensitive to normative influences than young adults (16–24 years old; Steinberg and Monahan, 2007). Therefore, the impact of descriptive norms highlighting desired behaviors (i.e., sufficient intake) compared with those that focus on problem behaviors (i.e., insufficient intake) on eating intentions and behavior is unclear.

When individuals identify with a group they are more motivated to adhere to in-group norms than out-group norms (Higgs, 2015; Reynolds et al., 2015; Tarrant et al., 2015). Young adulthood is the period throughout which individuals acquire a range of identities (e.g., student) and are motivated by their need to belong (Baumeister and Leary, 1995; Arnett, 2000). Within an eating behavior context, Louis et al. (2007) were the first to investigate the association between group identification strength and perceived eating norms in a longitudinal predictive study. They found high identifiers reported group-congruent intentions, whereas low identifiers did not. However, in a two-week follow-up, identification strength was not found to predict behavior (Louis et al., 2007). Further evidence suggests that the effect of identification strength on the influence of norms on eating behavior is not conclusive (Dempsey et al., 2018), with recent studies suggesting that high identification may result in both norm-divergent behavior (Banas et al., 2016) and convergent behavior (Liu et al., 2019).

The aim of this exploratory research was to investigate whether a descriptive norm message communicating a sufficient F&V intake norm is effective in improving F&V intake intentions and subsequent intake compared with a message communicating an insufficient F&V intake norm. Additionally, we explored whether the influence of the descriptive norm messages depends on the strength of student identification. To examine the effect of identity strength, an identity manipulation was included to categorize participants into distinct "low" and "high" identifier groups.

MATERIALS AND METHODS

Participants and Recruitment

Eligible participants were undergraduate students in the United Kingdom aged 18 years or above, and were recruited *via* social media (e.g., Facebook and Twitter) between April and June 2019. Power analysis using G*Power determined a target sample size of 128 participants for ANCOVA that is powered for fixed effects, main effects, and interactions, with alpha set at 0.05 and power at 0.80 (Cohen, 1992) to detect a medium effect size ($f=0.25$; Erdfelder et al., 2007). This estimate is consistent with previous research demonstrating that studies investigating the effects of eating norms usually detect a small to medium effect size (Robinson et al., 2014b; de Bruijn et al., 2015). Ethical approval was granted by the University Teaching and Research Ethics Committee at the University of St Andrews (MD14242).

Design

The study employed a randomized, 2×2 between-subjects, pretest/posttest design. The two independent variables were "Descriptive Norm" messages ("sufficient"/"insufficient" F&V intake norm) and "Identification Strength" ("low"/"high"). The study was completed online *via* Qualtrics which, after providing consent, automatically randomized participants in a 1:1 ratio to four groups. The dependent variables were: (a) F&V intake intentions following the norm-based message (see "Part 1") and (b) self-reported F&V intake at two-day follow-up (see "Part 2").

Materials

Identification Manipulation

The study involved a between-subjects identification manipulation to expose participants to statements loaded about positive and negative characteristics of student identity (**Table 1**). Two types of identification manipulations occurred following Greenaway et al.'s (2015) example to create "high" and "low" identifiers. Participants in the "High Identification" group received five moderately positive and five extremely negative student identity-related statements; the "Low Identification" group was presented with five moderately negative and five extremely positive statements (**Table 1**). Greenaway et al.'s (2015) manipulation posits that the manipulation prompts participants to agree with moderate statements and disagree with the extreme ones. This manipulation has been successfully used by Banas et al. (2016) to create "low" and "high" identifiers in their social norms study. In line with the original manipulation, to ensure participants were aware of the number and valence of selected statements, they were asked to count both the number of negative and positive statements they agreed with. The actual act of counting of the statements participants agree with is the identity primer itself, and the scores were used to indicate identity strength in the analysis. Following this, participants were presented with the norm manipulation (described below).

Norm Manipulation

Following the identification manipulation, participants were asked to rate the clarity of an infographic (**Figure 1**). Participants were shown one infographic which displayed either a "sufficient" or "insufficient" F&V intake norm alongside additional, unrelated norms (e.g., studying habits) based on a fictitious lifestyle study. Participants were asked to retain the presented information as there was a test afterward, which served as an attention check for their recall of norms.

Attention Check

Following the presentation the infographic, participants were asked to recall the percentage of students who eat a "sufficient"/"insufficient" amount of F&V. Answers were accepted to deviate ±10% from the norm presented to them (Banas et al., 2016).

Socio-Cognitive Constructs

Attitudes, perceived behavioral control, and intentions to consume sufficient F&V were assessed by items adapted from Ajzen's (2002) recommendations for creating a scale to measure these constructs in line with previous studies (e.g., Stok et al., 2014b; **Table 2**). Self-reported F&V intake was assessed by items adapted from Robinson et al. (2014b), which provide an accurate dietary recall over 24 h (Armstrong et al., 2000; **Table 2**). Guidance on how to determine portion sizes (~80 g) was provided for each question by an image taken from the Scottish Health Survey (Rose, 2018). Fruit and vegetable intake was self-reported separately.

Procedure

Part 1

Participants were invited to complete a 15-min "Lifestyle study" on United Kingdom undergraduate student behaviors. Consenting, eligible participants reported their baseline F&V

TABLE 1 | Identification manipulation items created following the example of Greenaway et al. (2015).

	"Low" identification	"High" identification
Extreme statements[1]	I identify extremely strongly with other undergraduate university students	I feel no affiliation with other undergraduate students
	It is essential for me that all my friends are undergraduate students	There is no point of doing an undergraduate degree
	I only want to participate in activities with people who are undergraduate students	Being an undergraduate university student opens up no career opportunities in the future
	My undergraduate degree offers me complete control over what I would like to study	Being an undergraduate university student means that all my time is dedicated to studying
	Being a university student means that I can be fully flexible in how I manage my time	There is no sense of community spirit among undergraduate students
Moderate statements[2]	There are some things I do not like about being an undergraduate student	In general, I like being an undergraduate student
	Studying on an undergraduate degree takes up a substantial amount of my free-time	I have friends who are undergraduate students
	I think it is good to have friends outside university	Being a university student provides me opportunities to meet new people
	Studying an undergraduate degree does not always mean that I study about areas that I am interested in	As an undergraduate student, it's mostly up to me how I manage my own time
	There are some things I do not like about being an undergraduate student	Being an undergraduate university student offers me the opportunity to learn about areas I am interested in

[1]*Statements more difficult to agree with.*
[2]*Statements easier to agree with.*

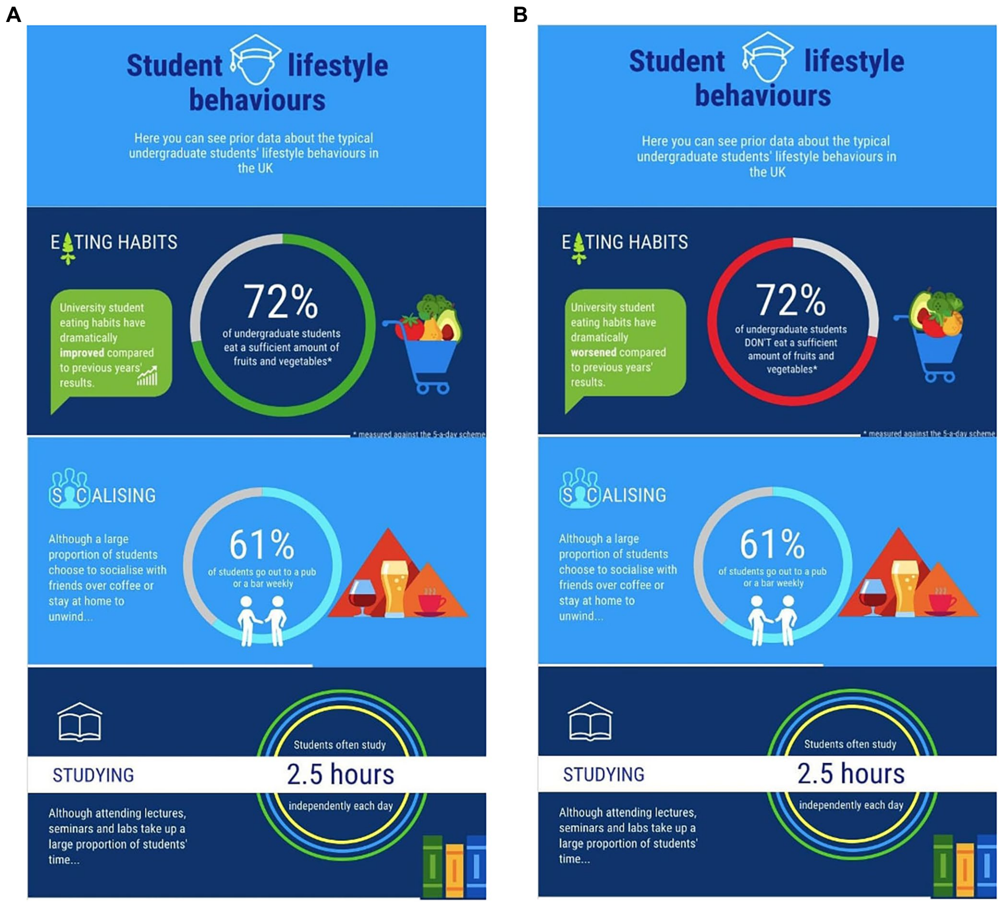

FIGURE 1 | (A,B) Infographic containing the "sufficient"/"insufficient" norm.

intake, self-identification as a "sufficient F&V eater," and socio-cognitive constructs (e.g., attitudes). As the true aim of the study was concealed from participants in an attempt to prevent social desirability bias (Miller et al., 2008), several filler questions were included (e.g., socializing habits), which were not analyzed. Following this, participants received the identification, and then the norm manipulations during the online survey. Demographics [age (year), gender, ethnicity, height (cm), weight (kg), student status (year and country), and dietary requirements] were collected to describe the sample. To match participant responses with the follow-up (see "Part 2" below), participants were guided to create a unique code (see Grube et al., 1989) and provided email addresses.

Part 2

Two days after Part 1, upon receipt of the automatic email invitation, participants were asked to self-report the number of F&V portions they consumed the previous day *via* the same 24 h fruit and vegetable online Qualtrics intake form that they answered in Part 1. Participants had the opportunity to enter a prize draw [Amazon voucher (4×£25)]. Upon submission of their answers, a participant debrief form detailed the true aim of the study.

Data Analyses

The research questions and the data analysis plan were pre-specified before the data were collected. Differences between the four manipulated groups in baseline F&V intake, demographics, and socio-cognitive constructs were assessed by one-way ANOVAs with group membership as a fixed factor. Manipulation and attention checks were assessed by two-way ANOVAs. Two-by-two ANCOVAs assessed the interaction and main effects of norms and identification manipulations on F&V consumption intentions and behavior (Rausch et al., 2003). Based on previous studies (Robinson et al., 2014a; Stok et al., 2014a), it was decided *a priori* to include attitudes, perceived behavioral control, self-identification as a "sufficient F&V eater," and baseline intake or intentions as covariates to reduce within-group error variance (Field, 2009). Significant interactions were followed up with Bonferroni-adjusted simple main effects comparisons (Price et al., 2017); significance was determined at $p < 0.05$. Data were analyzed by SPSS v24.

RESULTS

Descriptive Statistics

A total of 180 participants completed Part 1 ($M_{Age} = 20.36 \pm 1.64$), of which 112 (62.2%) were followed up in Part 2 (**Figure 2**).

TABLE 2 | Measures and corresponding example items, response range, and scoring.

Measures	No. items	Example item	Response range	Scoring	Cronbach's Alpha[1]
Socio-cognitive measures					
Identification as a "sufficient fruit and vegetable eater"	2	"I see myself as someone who eats a sufficient amount of fruit and vegetables."	Strongly disagree – Strongly agree	1 to 7[3]	0.90
Attitude	4	"Eating 5 portions of fruit and vegetables tomorrow for me would be…"	Unhealthy – Healthy Unpleasant – Pleasant Harmful – Beneficial Unenjoyable – Enjoyable	1 to 7	0.72
Perceived behavior control	4	"For me to eat 5 portions of fruit and vegetables tomorrow would be…"	Impossible – Possible	1 to 7	0.84
Intention to eat 5 portions of fruit and vegetables	4	"I intend to eat at least 5 portions of fruit and vegetables (5x80g) tomorrow…"	Strongly disagree – Strongly agree	1 to 7	0.94
Identification manipulation check	2	"Completing the questions at the beginning of the survey led me to identify as an undergraduate student."	Strongly disagree – Strongly agree	1 to 7	0.65
Outcome measures					
Intended portions to consume the next day	2	"How many portions of vegetables/fruit do you think you will consume tomorrow?"	Number of portions ranging from 0 to 10.5 or more		–
Intake (24h measure)[2]	2	"How many portions of fruit/vegetables did you eat yesterday?"	Number of portions ranging from 0 to 10.5 or more		–

[1]Cronbach's alpha was employed as a reliability coefficient, for which the desired value was ≥ 0.7 (Nunnally, 1978).
[2]This measure was used to assess both baseline and follow-up intake.
[3]A score of 7 indicates stronger identification/attitudes/perceived behavioral control/intentions; Composite scores were computed for all measures.

Participants not eligible ($n = 28$; e.g., <18–25> years old, not a student), and those who left the study before ($n = 117$) and after ($n = 20$) being presented with the infographic, were excluded. Sample participants displayed positive attitudes and perceived behavioral control toward consuming 5 portions of F&V a day, as shown by scores above each scale's mid-point (**Table 3**). The sample indicated a relatively high baseline F&V consumption, with a mean of 4.50 (SD = 2.86) F&V portions, of which 2.5 (SD = 2.02) and 1.98 (SD = 1.55) mean portions were fruit and vegetables, respectively.

Groups did not differ in socio-cognitive constructs, baseline F&V intake, or demographic characteristics (**Tables 3, 4**; $p > 0.115$). Additionally, the proportionate attrition (**Figure 2**) was unrelated to condition, demographics, baseline F&V intake, and socio-cognitive constructs ($p > 0.112$). Participants were predominantly White female students from Scottish universities who were normal weight (61%; **Table 4**; CDC, 2017).

Identification Manipulation Check

ANOVA revealed a non-significant difference between the "low" (4.73 ± 1.34) and "high" (5.07 ± 1.34) identification conditions, $F(1,179) = 2.97$, $p = 0.086$, indicating the manipulation was not fully successful.

Attention Check

A total of 76.1% of participants recalled the descriptive norms displayed by the infographics correctly. Participants rated the infographics as easy to understand and well-presented. There was a significant difference in descriptive norm recall between conditions, with a larger percentage of correct recalls in the "insufficient" (84%) than the "sufficient" condition (68%), $F(1,178) = 6.09$, $p = 0.015$, $\eta_p^2 = 0.03$.

Intentions

Intention to Eat >5 F&V Portions (Part 1)

ANCOVA revealed no main effects of norms or identification on fruit intake intentions. The norm by identification manipulation interaction was significant, which generated a small effect size (**Table 5**). Simple main effects analysis revealed that when presented with "insufficient" norms, participants in the "high" identification group reported intentions to eat approximately half a portion more fruit (Mean $\text{difference}_{\text{adjusted}} = 0.44$, $p = 0.05$) than participants in the "low" identification manipulation group (**Figure 3**). Additionally, "low" identifiers in the "insufficient" condition intended to consume significantly fewer portions (Mean $\text{difference}_{\text{adjusted}} = -0.49$, $p = 0.036$) than participants in the "sufficient" condition (**Figure 3**). No main effects (norm or identification) nor interactions were found for vegetable intake intentions (**Table 5**). No main effects nor interactions were found for "overall intentions" to consume ≥5 F&V portions the next day (**Table 5**).

Intake: Number of F&V Portions Consumed (Part 2)

Participants self-reported their F&V intake in the two-day follow-up (**Table 6**). No main effects (norm and identification) nor interactions were found for self-reported fruit intake two days post-intervention (**Table 7**). No significant main effects were revealed for norm nor identification on vegetable intake (**Table 7**). The norm by identification manipulation interaction was significant ($p = 0.034$), which generated a small to medium

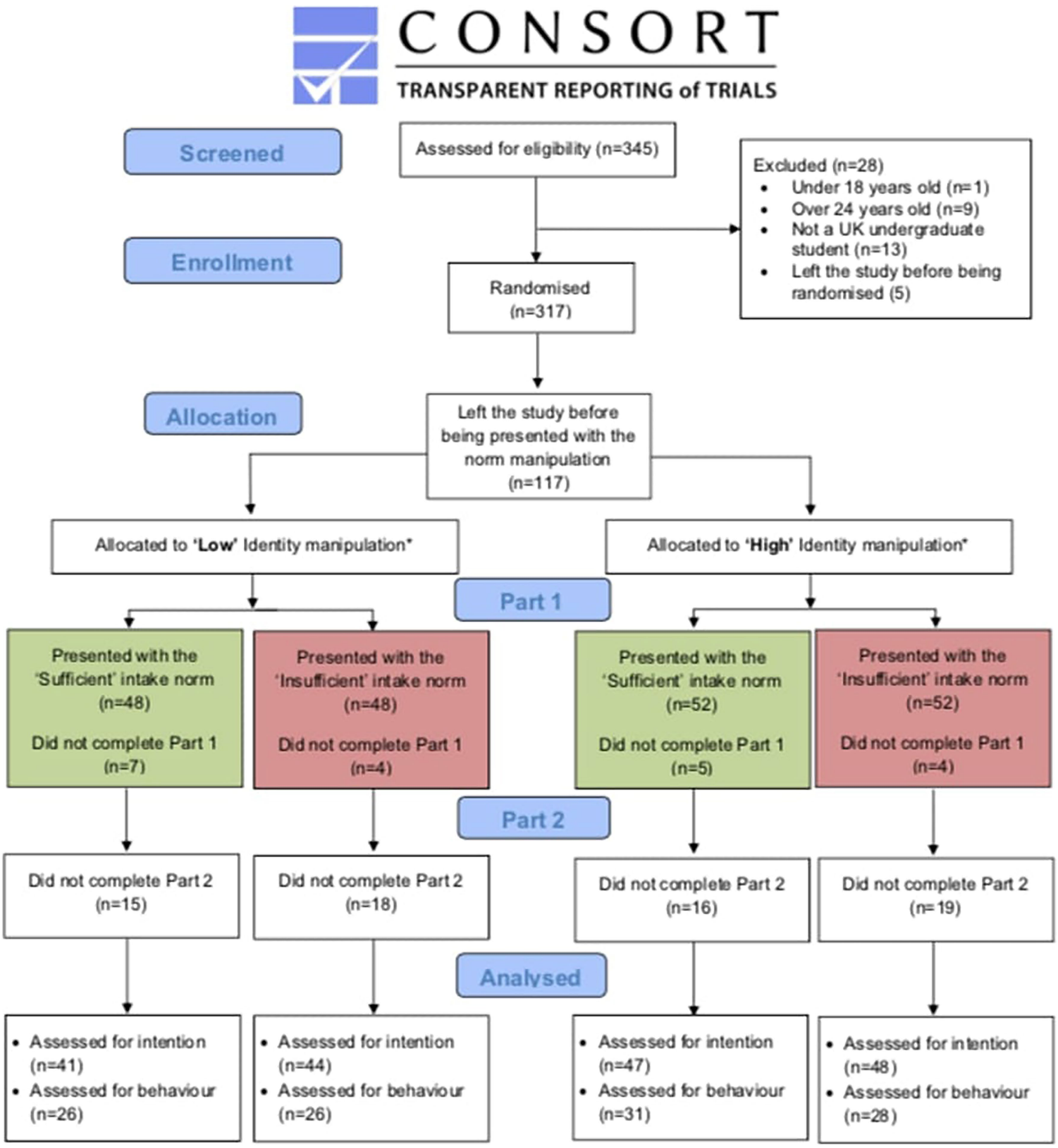

FIGURE 2 | Participant recruitment, allocation, and retention (CONSORT; Schultz et al., 2007). Asterisk indicates that out of the 317 individuals who were allocated to the "low" or "high" identification manipulation, 117 left the study before being presented with the infographics conveying the manipulated norms.

effect size (**Table 7**; **Figure 4**). Although it was not significant, simple main effects analysis revealed that upon receiving the "insufficient" intake norm, participants in the "high" identification consumed approximately half a portion more vegetables (Mean $\text{difference}_{\text{adjusted}} = 0.55$, $p = 0.095$) than participants in the "low" condition. Participants under the "high" identification manipulation who received the "sufficient" intake norm consumed fewer portions (Mean $\text{difference}_{\text{adjusted}} = -0.44$, $p = 0.179$) than participants receiving the "low" identity manipulation. Additionally, a non-significant, half-portion difference (Mean $\text{difference}_{\text{adjusted}} = 0.60$; $p = 0.079$) was detected between the two "low" identifier groups, with those in the "sufficient" norm condition consuming more vegetables.

DISCUSSION

This study compared the effect of a descriptive norm message communicating the "sufficient" F&V intake of in-group members with an "insufficient" F&V intake message, on immediate F&V intake intentions and subsequent intake at a two-day follow-up. Whether the impact of descriptive norms was dependent on student identification strength was also investigated by employing

TABLE 3 | Means (and standard deviations) of baseline socio-cognitive measures and fruit and vegetable intake.

		"Sufficient" fruit and vegetable intake norm ($n = 88$)		"Insufficient" fruit and vegetable intake norm ($n = 92$)	
Baseline measures		"Low" identification ($n = 41$)	"High" identification ($n = 47$)	"Low" identification ($n = 44$)	"High" identification ($n = 48$)
"Sufficient F&V eater" identification*		4.96 (1.50)	4.66 (1.70)	5.11 (1.90)	5.00 (1.81)
Attitude*		6.07 (0.93)	5.99 (1.02)	6.04 (1.08)	6.10 (0.85)
Perceived behavioral control*		6.02 (1.28)	5.88 (1.17)	6.04 (1.13)	6.02 (1.28)
Baseline fruit and vegetable intake	Fruit	2.09 (1.63)	1.64 (1.31)	1.99 (1.51)	2.24 (2.07)
	Vegetable	2.53 (2.13)	2.50 (1.82)	2.50 (2.04)	2.54 (2.16)
	F&V	4.63 (2.51)	4.13 (2.41)	4.49 (2.71)	4.78 (3.78)

Means are based on composite scores, ($N = 180$).

TABLE 4 | Participant demographics and breakdown of percentages ($N = 180$).

Characteristics		No. participants (%)	Sufficient F&V intake norm ($n = 88$)		Insufficient F&V intake norm ($n = 92$)	
			"Low" identification ($n = 41$)	"High" identification ($n = 47$)	"Low" identification ($n = 44$)	"High" identification ($n = 48$)
Gender	Female	141 (78.3)	37 (90.2)	36 (76.6)	35 (79.5)	33 (68.8)
	Male	38 (21.1)	4 (9.8)	10 (21.3)	9 (20.5)	15 (31.3)
	Prefer not to say	1 (0.5)	–	1 (2.1)	–	–
Year of study	1st	60 (33.3)	13 (31.7)	18 (38.3)	16 (36.4)	13 (27.1)
	2nd	48 (26.7)	15 (36.6)	12 (25.5)	13 (29.5)	8 (16.7)
	3rd	28 (15.6)	5 (12.2)	5 (10.6)	6 (13.6)	12 (25.0)
	4th	38 (21.1)	6 (14.6)	9 (19.1)	9 (20.5)	14 (29.2)
	5th	6 (3.3)	2 (4.9)	3 (6.4)	-	1 (2.1)
Dietary requirements	Vegetarian/Pescatarian	39 (21.7)	9 (21.6)	6 (12.7)	6 (13.6)	18 (37.5)
	Vegan	12 (6.7)	3 (7.2)	3 (6.4)	4 (9.1)	2 (4.2)
	Allergies/sensitivity/restriction	9 (5.4)	2 (4.8)	3 (6.3)	3 (6.9)	2 (4.2)
	No requirements	120 (66.7)	28 (68.3)	35 (74.5)	31 (70.5)	26 (54.2)
Ethnicity	Asian, Chinese	13 (7.2)	4 (9.7)	2 (4.2)	2 (4.5)	5 (10.5)
	Black	2 (1.1)	–	–	1 (2.3)	1 (2.1)
	Mixed/Other	4 (2.3)	–	1 (2.1)	1 (2.3)	2 (4.2)
	White	159 (88.3)	36 (87.8)	44 (93.6)	40 (90.9)	39 (81.3)
	Prefer not to say	2 (1.1)	1 (2.4)	-	–	1 (2.1)
Country of study[1]	Scotland	166 (92.2)	36 (87.8)	43 (91.5)	42 (95.5)	45 (93.8)
	England	14 (7.8)	5 (12.2)	4 (8.5)	2 (4.5)	3 (6.3)
Body Mass Index (BMI)[2]	Underweight (<18.5)	17 (9.4)	5 (12.2)	3 (6.4)	4 (9.1)	5 (10.4)
	Normal (18.5–24.9)	110 (61.1)	26 (63.4)	31 (66.0)	28 (63.6)	25 (52.1)
	Overweight (25.0–29.9)	32 (17.8)	6 (14.6)	8 (17.0)	6 (13.6)	12 (25.0)
	Obese (>30.0)	8 (4.4)	3 (7.3)	1 (2.1)	3 (6.8)	1 (2.1)
	Not available	13 (6.7)	1 (2.4)	4 (8.5)	3 (6.8)	5 (10.4)

[1]There were no participants who studied at Welsh or Northern Irish universities.

[2]Calculated based on self-reported height (cm) and weight (kg) and classified according to the Centre for Disease Control and Prevention (CDC, 2017) cut-off points for adults aged ≥18 years.

a manipulation to categorize students as "low"/"high" identifiers. The manipulation was not fully successful in creating distinct "low"/"high" identifiers, and participants in the "low" identification group displayed relatively high identification, which is frequently observed in studies (Stok et al., 2012; Banas et al., 2016; Liu and Higgs, 2019). We found that participants in the "low" identification group intended to and acted norm-congruently, while participants in the "high" identification group intended to and acted against the presented norms.

Some social norms research asserts that higher identification predicts norm-congruent behavior (Louis et al., 2007; Stok et al., 2012, 2014a). For example, in a similar study, Liu et al. (2019) investigated the relationship between descriptive norms and identification strength on participants' F&V intake. The researchers primed one group's student identity and showed participants a flyer or a poster either communicating descriptive norms about most students consuming over 5 portions of F&V daily or a health message conveying the benefits of eating 5-a-day. They found the primed group consumed 40 g more F&V from a buffet than the non-primed group. In contrast, the present data show that only the "low" identification group participants' fruit intake intentions and vegetable intake were norm-congruent. Several explanations may be attributable to the differences in the current findings and Liu et al.'s (2019) experiment. Crucially,

TABLE 5 | ANCOVA table for fruit and vegetable intake intentions (Part 1).

Independent variables	*F*(1,172)			*p*			η_p^2		
	Fruit	Vegetable	Overall intention[2]	Fruit	Vegetable	Overall intention[2]	Fruit	Vegetable	Overall intention[2]
Norm manipulation	1.09	0.97	0.03	0.299	0.326	0.862	0.01	0.01	0.00
Identification manipulation	0.52	0.85	1.02	0.474	0.357	0.314	0.00	0.01	0.01
Norm × Identification manipulation	4.11	2.25	0.10	0.044*	0.136	0.757	0.02	0.01	0.00
Covariates									
Baseline intake[1]	119.59	102.02	9.48	0.001*	0.001*	0.002*	0.41	0.37	0.05
Attitude	2.00	5.38	38.35	0.159	0.020*	0.001*	0.01	0.03	0.18
Perceived behavioral control	1.44	0.15	4.92	0.233	0.700	0.028*	0.01	0.00	0.03
"Sufficient fruit and vegetable eater" identification	0.22	5.95	44.69	0.642	0.016*	0.001*	0.00	0.03	0.21

*Significant at $p < 0.05$.
[1]Baseline intake refers to corresponding food type (fruit/vegetable/fruit and vegetable).
[2]Overall intentions refer to intention to eat 5 or more portions of fruit and vegetables the next day; (*N* = 180).

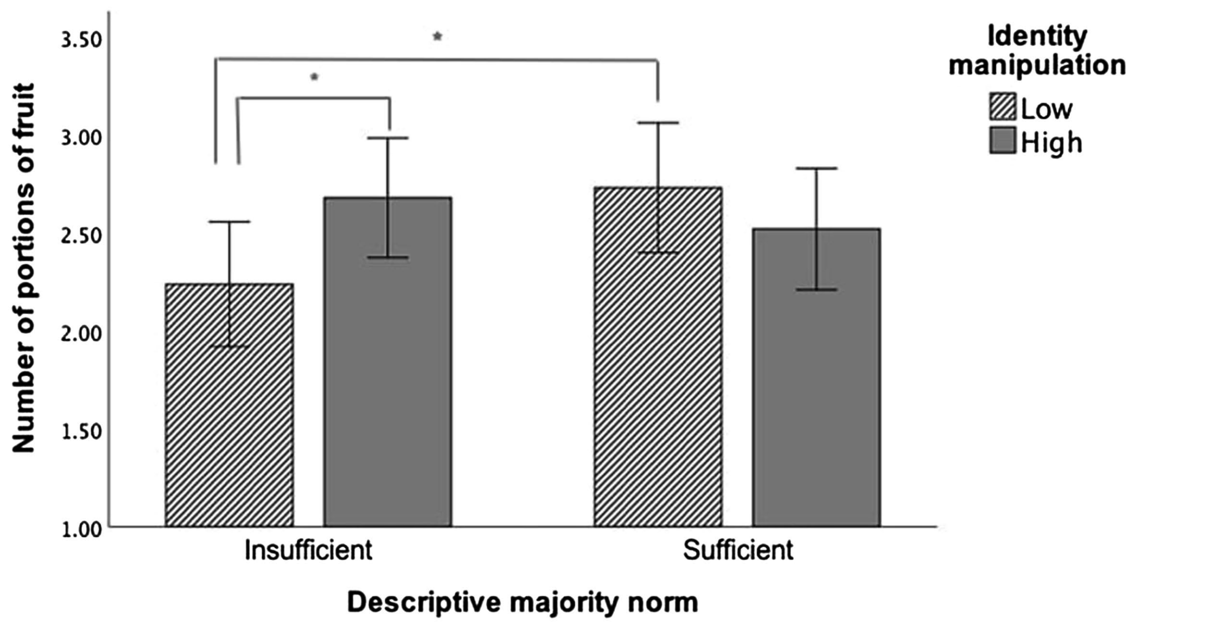

FIGURE 3 | Bar graph illustrating the cross-over interaction of the Norm ("sufficient"/"insufficient") and Identification ("low"/"high") manipulations on the number of portions of fruit participants intended to consume the following day. The means are adjusted for baseline intake, attitudes, perceived behavioral control, and identification as a "sufficient fruit and vegetable eater." Error bars display 95% confidence intervals. Asterisk indicates significant difference at $^*p < 0.05$. (*N* = 180).

Liu et al.'s (2019) sample consumed 2 F&V portions at baseline, whereas our sample reported 4.5 portions. Previous studies have indicated substantial differences in the effect of norms on "high" and "low" F&V consumers, with "low" consumers being more prone to match norms (Schultz et al., 2007; Robinson and Higgs, 2012; Robinson et al., 2014a; Verkooijen et al., 2015). Therefore, the contrasting findings could be attributed to baseline F&V intake. Additionally, the difference between the identity manipulations used by Liu et al. (2019) and in the present study may also account for the observed contradictory results.

The present data also suggest that participants in the "high" identification group actually diverged from norms. This manifested in the present study in two ways. Firstly, participants in the "high" identification group intended to eat more fruit and increased their vegetable intake upon receiving the "insufficient" descriptive norm, although this was not significant. This may be explained by their desire not to be associated with a group which has unfavorable norms (Berger and Heath, 2007; Berger and Rand, 2008), leading to a compensatory behavior. Secondly, participants in the "high" identification group intended to eat fewer

TABLE 6 | Means (and Standard Deviations) for fruit and vegetable intake at two-day follow-up (Part 2).

Follow-up intake	"Sufficient" fruit and vegetable intake norm ($n = 57$)		"Insufficient" fruit and vegetable intake norm ($n = 55$)	
	"Low" Identification ($n = 26$)	"High" Identification ($n = 31$)	"Low" Identification ($n = 26$)	"High" Identification ($n = 29$)
Fruit	2.52 (1.84)	1.65 (1.23)	2.08 (1.63)	2.43 (1.39)
Vegetable	2.69 (1.85)	1.87 (1.23)	2.40 (1.60)	2.87 (1.78)
F&V	5.21 (3.30)	3.52 (1.98)	4.48 (2.76)	5.12 (2.85)

TABLE 7 | ANCOVA table for fruit and vegetable intake at two-day follow-up (Part 2).

Independent variables	F (1, 103)		p		η_p^2	
	Fruit	Vegetable	Fruit	Vegetable	Fruit	Vegetable
Type of Norm	0.20	0.19	0.776	0.655	0.00	0.00
Identification manipulation	0.11	0.07	0.918	0.739	0.00	0.00
Type of Norm × Identification manipulation	0.35	4.606	0.558	0.034*	0.00	0.04
Covariates						
Portions intended to consume[1]	65.98	50.24	0.001*	0.001*	0.39	0.33
Attitude	3.34	0.01	0.071*	0.908	0.03	0.00
Perceived behavioral control	0.52	1.97	0.472	0.163	0.01	0.01
"Sufficient fruit and vegetable eater" identification	1.26	0.00	0.218*	0.264	0.01	0.00

**Significant at $p < 0.05$.*
[1]Corresponding food type (Fruit/Vegetable); ($N = 112$).

fruit portions and (non-significantly) decreased their vegetable intake by half a portion upon receiving the "sufficient" descriptive norm. The finding corroborates Banas et al. (2016), who demonstrated that "high" identifiers chose calorific food items from an online menu when presented with "healthy" descriptive norms, indicating the presence of ironic effects. Banas et al. (2016) suggested that observed ironic effects could be explained by vicarious licensing. Vicarious licensing posits when high identifiers perceive their in-group members making progress in achieving a goal (e.g., eating healthily), they may give an individual license to themselves (e.g., choose unhealthy food; Kouchaki, 2011). This ironic effect has primarily been associated with hedonic consumption, where one is offered an alternative choice (Wilcox et al., 2009; De Witt Huberts et al., 2012). However, as the current study did not investigate vicarious licensing, nor offer an alternative choice, a definitive conclusion cannot be drawn as to whether this is the underlying mechanism for the findings. Taken together, the data suggest that understanding of the moderating effects of identification on responses to eating norms requires further investigation.

In the present study, an approximate half-portion (~40 g) difference (non-significant) was consistently observed between descriptive norm conditions, which is noteworthy, given that long-term school-based dietary interventions for children (5–12 years) can only demonstrate an increase in F&V intake by an average of one-quarter to one-third of a portion (~20–30 g; Evans et al., 2012). The half-portion difference is clinically relevant given the dose-related relationship between F&V intake and diseases such as cardiovascular disease and cancer (Aune et al., 2017), and evidence indicating that each additional serving of fruit or vegetable a day is associated with 5–6% reduced risk of all-cause mortality (Wang et al., 2014).

It is important to note that as the manipulation was not fully successful to create distinct "low"/"high" identifiers, participants in the "low" identification group displayed relatively high identification, which is frequently observed in studies (Stok et al., 2012; Banas et al., 2016; Liu and Higgs, 2019). Consequently, the two identification groups could be regarded as "identifiers" and "extreme identifiers," whereby "identifiers" perceive descriptive norms relevant, and thus act norm-congruently, a well-documented finding (Cruwys et al., 2012; Stok et al., 2012; Reynolds et al., 2015). Our findings showed that the intention and consumption of "identifiers" were poorer in the "insufficient" condition, which may be attributed to the "backlash" effect (Cialdini, 2003), which is an undesired behavioral outcome following exposure to undesired norms conveying problem behaviors about one's in-group.

Our findings in relation to the "sufficient"/"desired" descriptive majority norms compared with "problem"/"insufficient" norms on intention and behavior show that when identity is not taken into account, there were no differences in their impact. These findings support the only similar investigation conducted to date by de Bruijn et al. (2015), who found desired descriptive norms had no effect on fruit intake intentions and intake when compared with undesired, "problem norm" content. These findings are broadly consistent with available field research on drinking behavior (Foxcroft et al., 2015). However, an explanation for the

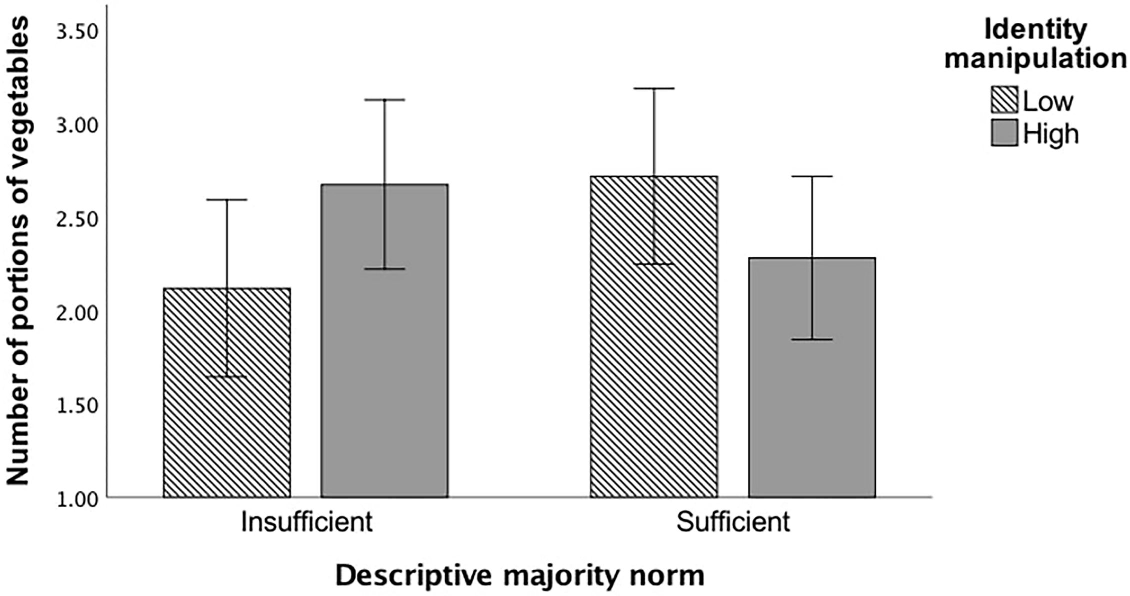

FIGURE 4 | Bar graph illustrating the cross-over interaction of the Norm ("sufficient"/"insufficient") and Identification ("low"/"high") manipulations on the number of vegetable portions participants consumed at follow-up. The means are adjusted for attitudes, perceived behavioral control, intentions, and identification as a "sufficient fruit and vegetable eater" as covariates. Error bars represent 95% confidence intervals. ($N = 111$).

non-significant differences between descriptive norms may also lie in participants' norm recall rates. Participants in the "insufficient" condition recalled norms more successfully than those in the "sufficient" condition, suggesting the bogus "sufficient" norm was perhaps perceived as inaccurate. In support of this suggestion, research shows students are generally perceived to be "unhealthy" (Tarrant and Butler, 2011) with students often overestimating peer's poor health behaviors (Neighbors et al., 2006).

Strengths

A strength of this investigation is the norm-conveying infographics—regarded as well presented and clear by participants—which were designed to resemble content encountered in daily life. Therefore, the infographics are ecologically valid and can be employed in future research. Furthermore, the concealment of true study objectives during recruitment and the absence of the experimenter throughout data collection lessened the likelihood of social desirability bias, a bias commonly experienced in eating behavior research (Steim and Nemeroff, 1995; Nix and Wengreen, 2017). Overall, the investigation contributes to the limited experimental social norm studies exploring healthy eating and employing a follow-up self-reported intake measure, as opposed to immediate food choice measures or intention only (Robinson, 2015; Stok et al., 2018).

Limitations and Recommendations for Future Research

A limitation of this study relates to the identification manipulation which was not fully successful in creating distinct "low"/"high" identifiers, thereby limiting variability to detect a moderating role for identification on descriptive norm messages. Future research should aim to improve the manipulation to verify the direction of the interaction of descriptive norms and identification strength. Additionally, the analysis of intake was underpowered due to attrition and is acknowledged as a limitation. Furthermore, the norms were fictitious and norm recall rates were significantly different between the norm conditions. It is possible that the insufficient F&V intake norm manipulation seemed more credible compared to the sufficient norm manipulation to the participants. Future studies may test pre-existing norm perceptions and/or assess whether the norms are regarded as credible. An unexpected finding was the discrepancy observed between F&V intake intentions and behavior. Although measuring intentions is appropriate in predicting behavior (Kellar and Abraham, 2005; Ickes and Sharma, 2011), intentions do not necessarily manifest (Lien et al., 2001; Sniehotta et al., 2005) resulting in an intention-behavior gap.

The "lifestyle study" ostensibly attracted health-motivated participants, potentially leading to selection bias. This may explain why participants identified as "sufficient F&V eaters" and displayed relatively strong attitudes, perceived behavioral control, and intentions to eat 5-a-day. Additionally, the sample's BMI distribution (61% healthy BMI) is not representative of adults in Scotland, as recent evidence indicates that prevalence of overweight (including obesity) is 65% for this cohort (Bardsley, 2018). Furthermore, asking participants to self-report their sufficient F&V eater identity may have had a priming effect that impacted the results.

As participants' self-reported baseline consumption was at 4.5 F&V portions, which conforms approximately to the 5-a-day norm presented, it is plausible that a ceiling effect was observed.

The sample's baseline consumption is substantially higher than intake levels reported in national surveys of young adults', and cross-sectional investigations of undergraduate students' eating practices (Tanton et al., 2015; Rose, 2018; Sprake et al., 2018). This may be due to the high proportion of vegetarian/vegan participants at 28.4% in the sample, who typically eat more F&V than meat-eaters (Walsh et al., 2017). Overall, the external validity of the sample is thus limited, which is furthered by the predominant participation of white, female students studying in Scotland. Future research obtaining larger and demographically diverse samples displaying the nationally observed low F&V consumption is warranted.

Practical Implications

The finding that participants in the "low" identification group intended to and consumed fewer portions when presented with "insufficient" descriptive norms tentatively suggests that this kind of normative content may instigate unwanted outcomes (i.e., "backlash effect"), and therefore, conveying descriptive norms about problem behaviors in health promotion material should be cautioned. Additionally, the present findings add to the disagreement in the literature regarding the direction of the norm×identification interaction due to potential ironic effects for participants in the "high" identification group' intentions and behavior. Hence, these findings warrant further investigations of the underlying mechanisms, such as vicarious licensing, to offer a solution for harnessing the benefits of in-group identification in health promotion.

CONCLUSION

Although descriptive norms offer a cost-effective and simple approach to improve F&V intake intentions and behavior, and are successful when compared with no-norm controls and health messages (Robinson et al., 2014a), their effectiveness has not yet been demonstrated compared with undesired normative content in an eating behavior context. However, descriptive norms influenced fruit intake intentions and vegetable intake when investigated for their interaction with the identification manipulation, with participants in the "low" identification group acting norm-congruently, and participants in the "high" identification group diverging from the presented norms. The latter potentially suggests the ironic effects of high identification on behavior. Whether the findings generalize to other health behavior contexts, and to the general young adult population who would benefit from F&V intake improvement, remains subject to further investigation.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University Teaching and Research Ethics Committee at the University of St Andrews (MD14242). The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Measuring Ostracism-Induced Changes in Consumption of Palatable Food: Feasibility of a Novel Behavioral Task

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Purpose: Ostracism is a highly aversive interpersonal experience. Previous research suggests that it can increase consumption of highly palatable food in some individuals, but decrease it in others. Thus, we developed the Cyberball-Milkshake Task (CMT), to facilitate research investigating individual differences in ostracism's effects on consumption of highly palatable food. We present data on feasibility for the CMT in a sample of young adult women.

Materials and Methods: Participants were 22 women, 18–30 years old, reporting very low or very high levels of emotional eating at screening. Participants performed the CMT, which consisted of 12 trials. Each trial included: playing a round of Cyberball (a computerized game of catch with fictitious "other participants" programmed to either include or exclude the participant); viewing a chocolate image; and then consuming a participant-determined amount of milkshake. Participants subsequently played an additional inclusion and exclusion round of Cyberball, each immediately followed by questionnaires assessing current mood and recent Cyberball experience.

Results: Cyberball exclusion (vs. inclusion) was associated with large, significant increases in reported ostracism and threats to self-esteem; exclusion's effects on affect were in the expected direction (e.g., increased negative affect), but generally small and non-significant. Milkshake intake was measurable for 95% of participants, on 96% of trials. Intake decreased quadratically across trials, with a steep negative slope for low trial numbers that decreased to the point of being flat for the highest trial numbers.

Discussion: The CMT is a generally feasible approach to investigating ostracism's effects on consumption of highly palatable food. The feasibility (and validity) of the CMT may benefit from modification (e.g., fewer trials and longer rounds of Cyberball). Future research should examine whether performance on a modified version of the CMT predicts real-world behavior in a larger sample.

Keywords: stressor, interpersonal relations, ostracism, rejection, emotion, eating behavior, palatable food, eating disorder

INTRODUCTION

Ostracism and rejection are highly aversive interpersonal experiences that cause pain and distress (Williams, 2007), at least in Western cultures (Uskul and Over, 2017). These experiences can also threaten fundamental intrapersonal needs, such as feelings of belonging and self-esteem (Hartgerink et al., 2015), and can result in increased negative (Williams, 2007) and decreased positive (Lustenberger and Jagacinski, 2010) affect. Ostracism and rejection can also elicit a wide range of behavioral responses ranging from prosocial to antisocial. Notably, although these behaviors may serve to fulfill needs threatened by ostracism, they are not necessarily adaptive for the ostracized individual (Williams, 2007).

With respect to eating behavior, several experimental studies have examined whether ostracism affects consumption of highly palatable food in general adult samples. In two mixed-gender samples, ostracism or rejection had a main effect on cookie consumption, with ostracized or rejected participants consuming two to three times as many cookies immediately after the experience, compared to included or accepted participants (Baumeister et al., 2005; Oaten et al., 2008). In contrast, three other studies found that ostracism led to increased consumption of highly palatable food only for certain individuals, or only in certain conditions. In a mixed-gender sample, participants reporting habitual stress hyperphagia (specifically, a tendency to eat more in response to stress caused by others) ate more ice cream when rejected than accepted, whereas participants reporting habitual stress hypophagia exhibited the opposite pattern of ice cream consumption (Sproesser et al., 2014). Similarly, in a study of women, participants scoring high on self-reported restrained eating ate more after rejection than after achievement-oriented stressors and a control condition, but the same was not true for women low on restraint (Tanofsky-Kraff et al., 2000). In a study of African-American women, ostracized (vs. included) participants ate more potato chips (although not chocolate candy), and only when excluded by white women and not when excluded by other African-American women (Hayman et al., 2015). Collectively, these studies suggest that some individuals consume more highly palatable food in response to ostracism, but that the effects of ostracism on eating behavior likely differ across individuals.

In order to facilitate research investigating individual differences in ostracism's effect on eating behavior, we developed the Cyberball-Milkshake Task (CMT) to examine the effects of ostracism on consumption of a highly palatable food, namely, chocolate milkshake. In the CMT, ostracism is induced *via* Cyberball, a computerized game of catch with fictitious other participants who are programmed to either include or exclude the participant, with exclusion during Cyberball shown to consistently induce social distress (Williams and Jarvis, 2006). We aimed to develop a task that, with some adaptation for the neuroimaging context, could be used to investigate the neural underpinnings of ostracism's effects on eating behavior (Sebastian et al., 2011). The primary aim of the present study was to examine task feasibility in a sample of individuals reporting varying eating patterns. In particular, we aimed to test whether brief, repeated rounds of exclusion during Cyberball would be sufficient to evoke feelings of ostracism, threaten intrapersonal needs, and increase negative and decrease positive affect. We also sought to assess whether milkshake intake could be measured on a trial-by-trial basis. Our secondary aim was to preliminarily examine how ostracism affected milkshake intake in the sample overall, and among individuals reporting varying levels of emotional eating on the Dutch Eating Behavior Questionnaire (DEBQ; van Strien et al., 1986). Because Cyberball ostracism has not consistently increased food intake (Oaten et al., 2008; Hayman et al., 2015), we did not have an *a priori* hypothesis regarding whether ostracism would increase milkshake intake in the sample as a whole. However, given evidence that Cyberball can increase negative affect (Williams, 2007), together with evidence that high self-reported emotional eating can predict greater food intake following a negative mood induction (van Strien, 2010), we hypothesized that ostracism would increase intake in individuals reporting higher levels of emotional eating.

MATERIALS AND METHODS

Participants

Participants were recruited from the community in response to advertisements seeking young women (including those experiencing binge-eating) for a study on "cognitive processing and behavior," posted on Rally,[1] and at area colleges/universities, professional and vocational training schools, and retail locations.

Participants (see **Table 1**) were 18- to 30-year-old adults identifying primarily as female in gender, a group at increased risk of eating disorders (Hudson et al., 2007; Javaras and Hudson, 2015). To increase the likelihood that participants would demonstrate a range of changes in milkshake intake in response to Cyberball exclusion, we selected participants with either very low or very high responses (average response <1.6, or >3.6, respectively) to a subset of modified items from the Emotional Eating subscale of the DEBQ (Bohon et al., 2009) at screening. We did not exclude individuals with eating disorders (other than anorexia nervosa) or with most other psychiatric disorders. Additional eligibility criteria (see **Supplementary Material Section 1**) were intended to ensure safety and to reduce the likelihood that participants would respond atypically to Cyberball, would consume too little milkshake to be measurable, would be aware of the CMT measurement aim, or would be unable to complete the study protocol. For example, individuals with anorexia nervosa were excluded because avoidance of high calorie foods, especially those high in fat (Mayer et al., 2012), could result in little to no milkshake being consumed.

Of 22 eligible participants, one did not complete the task (for reasons unrelated to the study), and one participant was removed from analysis after preliminary inspection revealed highly implausible values calculated for milkshake intake (e.g., a calculated value of −300 g), which suggested measurement error.

[1]https://rally.partners.org

TABLE 1 | Demographic and other information for participants.[a]

	Low self-reported emotional eating[b] (*n* = 9)			High self-reported emotional eating[b] (*n* = 11)		
Age	23.2	(4.0)	[18, 28]	23.1	(3.8)	[18, 30]
Race						
American Indian or Alaska Native	0	(0.0%)		0	(0.0%)	
Native Hawaiian or Other Pacific Islander	0	(0.0%)		0	(0.0%)	
Asian	1	(11.1%)		0	(0.0%)	
Black or African-American	0	(0.0%)		0	(0.0%)	
White	7	(77.8%)		10	(90.9%)	
Other	1	(11.1%)		1	(9.1%)	
Ethnicity						
Hispanic or Latina	1	(11.1%)		1	(9.1%)	
Non-Hispanic or Latina	8	(88.9%)		10	(90.9%)	
Body mass index[c]	24.7	(5.0)	[20.2, 32.4]	24.5	(5.0)	[19.1, 36.0]
DEBQ Emotional Eating	1.5	(0.6)	[1.0, 2.9]	3.4	(0.7)	[1.9, 4.2]
Past psychiatric diagnoses[d]						
Major depressive disorder	0	(0.0%)		5	(45.5%)	
Panic disorder	0	(0.0%)		0	(0.0%)	
Anorexia nervosa	0	(0.0%)		2	(18.2%)	
Restricting	0	(0.0%)		1	(9.1%)	
Binge-eating/purging	0	(0.0%)		1	(9.1%)	
Bulimia nervosa	1	(11.1%)		0	(0.0%)	
Binge-eating disorder	1	(11.1%)		3	(27.3%)	
Current psychiatric diagnoses[d]						
Attention-deficit/hyperactivity disorder	0	(0.0%)		1	(9.1%)	
Combined	0	(0.0%)		0	(0.0%)	
Predominantly inattentive	0	(0.0%)		1	(9.1%)	
Predominantly hyperactive/impulsive	0	(0.0%)		0	(0.0%)	
Major depressive disorder	0	(0.0%)		1	(9.1%)	
Social anxiety disorder	1	(11.1%)		1	(9.1%)	
Panic disorder	0	(0.0%)		0	(0.0%)	
Agoraphobia	0	(0.0%)		0	(0.0%)	
Generalized anxiety disorder	0	(0.0%)		0	(0.0%)	
Obsessive–compulsive disorder	0	(0.0%)		0	(0.0%)	
Posttraumatic stress disorder	0	(0.0%)		0	(0.0%)	
Bulimia nervosa	0	(0.0%)		1	(9.1%)	
Binge-eating disorder	0	(0.0%)		2	(18.2%)	
Alcohol use disorder (12 mo.)	1	(11.1%)		4	(36.4%)	
Non-alcohol substance use disorder (12 mo.)	0	(0.0%)		1	(9.1%)	

DEBQ, Dutch Eating Behavior Questionnaire.

[a]For continuous variables, statistics include mean (standard deviation) [range]. For categorical variables, statistics include number (percentage) for each category.

[b]Participants had low or high average responses to a subset of modified items from the DEBQ Emotional Eating scale at screening.

[c]Two individuals with low self-reported emotional eating were missing body mass index values due to equipment problems.

[d]Disorders that were exclusionary (e.g., lifetime psychotic disorder and current/recent anorexia nervosa) are not included in table.

Procedures

Participants were asked not to consume alcohol, nicotine, recreational drugs, or excessive caffeine on the day before or the day of the study visit, and to eat a mid-day meal (e.g., turkey sandwich and piece of fruit) between 12-1 pm on the day of the visit. The 3.5-h visit included: milkshake tasting, to ensure that participants liked the milkshake; several semi-structured interviews assessing medical and psychiatric history; several "initial" questionnaires; an approximately 15 min break; a 15 min baseline period, during which participants listened to music (John Adams' *Common Tones in Simple Time*) previously used in neutral mood inductions (Bohon et al., 2009); the CMT, which occurred at approximately 3:30 pm, followed by completion of several "task-related" questionnaires; part one of a funnel debriefing interview; rating of chocolate images used in the CMT; "final" questionnaires, which included the questionnaires most likely to cue participants to the CMT's measurement aim; anthropometric measurement, including height and weight; part two of the funnel debriefing interview; and debriefing and safety assessment.

Participants received monetary compensation for adherence to the pre-visit instructions and for the study visit. Participants provided informed consent before beginning any study procedures, and the study was approved by the MassGeneral Brigham Institutional Review Board.

Cyberball-Milkshake Task

The CMT was coded in Python 3.8, using the PsychoPy package v1.84.2. Participants played 12 trials of the CMT on a desktop computer. Each trial consisted of three phases (the Cyberball, Chocolate Image, and Milkshake Intake phases; see **Figure 1**), each separated by viewing a fixation cross.

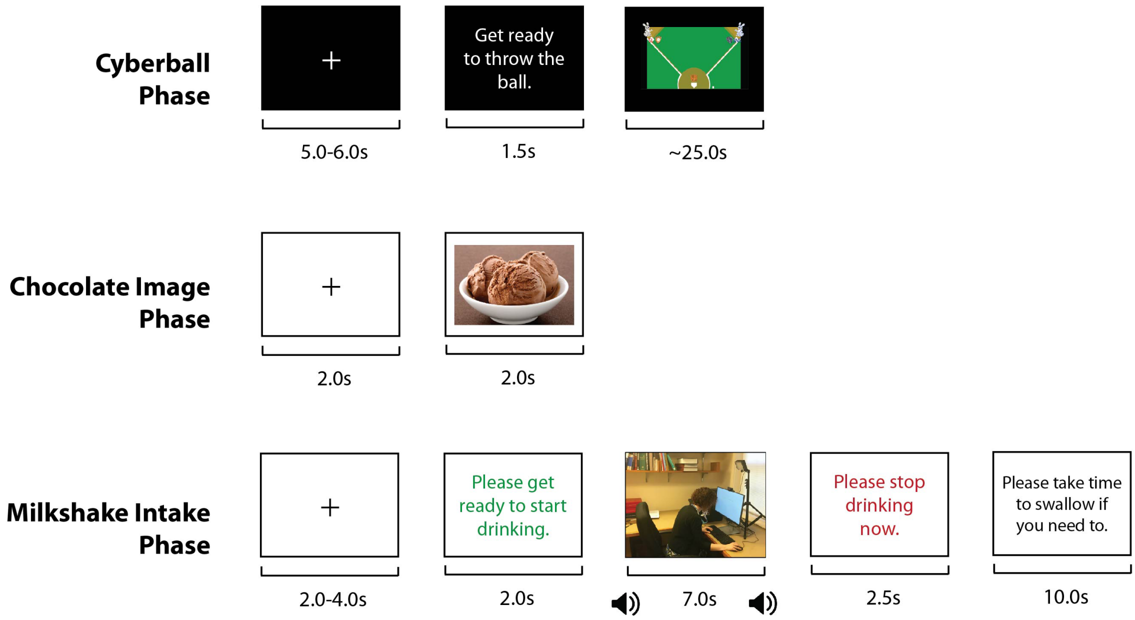

FIGURE 1 | Depiction of one trial of the Cyberball-Milkshake Task. The figure illustrates the three phases of each trial. The task included 12 trials, 6 inclusion, and 6 exclusion, depending on whether the fictitious "other players" included or excluded, respectively, the participant during the Cyberball phase of the trial.

The 25 s Cyberball phase was based on a modified version of Cyberball designed for use with functional magnetic resonance imaging (Sebastian et al., 2011). The Cyberball phase consisted of either an exclusion round or an inclusion round of Cyberball. During exclusion rounds, the two other players never threw to the participant and threw only to each other, and during inclusion rounds, the other players over-included the participant, throwing to her with probability of 0.8 (Sebastian et al., 2011).

During the 2 s Chocolate Image phase, the participant passively viewed an image of a chocolate dessert (e.g., chocolate ice cream). Image order was randomized across participants. Since the participant could neither see nor smell the actual milkshake due to the experimental setup, the Chocolate Image Phase was included to provide a visual cue for milkshake consumption. The intent of including this phase was to better mimic real-world milkshake consumption, where milkshake cues (e.g., visual and olfactory) would be present and could potentiate ostracism's effect on milkshake intake. Additionally, in a neuroimaging context, inclusion of the Chocolate Image phase would allow comparison of how exclusion versus inclusion affected activation in response to highly palatable food, especially given that it would likely be infeasible to analyze activation during the subsequent Milkshake Intake phase due to the confound of head motion.

During the 7 s Milkshake Intake phase, participants used a straw to consume a participant-determined amount of chocolate milkshake, the type of highly palatable food preferentially craved in response to stress and negative emotion (Domoff et al., 2014), but also avoided during dietary restriction. Milkshake intake during each trial was calculated based on the change in the milkshake's weight, measured by a concealed digital scale.

Participants first completed a practice trial of the CMT with study staff present. During the practice trial, participants did not actually consume any milkshake, to reduce the risk of satiation during the task. Participants then completed the actual CMT while alone in the study room. The CMT comprised 6 inclusion trials and 6 exclusion trials in a pseudorandomized order, such that the same trial type (i.e., inclusion or exclusion) did not occur more than two times in a row (Sebastian et al., 2011). After completing the CMT, participants completed a final inclusion round and a final exclusion round (order counterbalanced) of Cyberball. Immediately after each final Cyberball round, the computer instructed participants to complete a packet of "task-related" questionnaires.

More detailed information about the CMT is presented in **Supplementary Material Section 2**.

Interviews and Questionnaires

The interviews included the MINI International Neuropsychiatric Interview, English version 7.0.0, for DSM-5 (Sheehan, 2015), which was modified to assess both current and lifetime diagnoses of eating disorders.

The "task-related" questionnaires included: several scales assessing current affect or mood, including a mood scale containing bipolar items (e.g., happy/sad), the Implicit Positive and Negative Affect Test (IPANAT; Quirin et al., 2009), and several subscales from the Profile of Mood States 2-Adult Short Form (POMS-2-ASF; Lin et al., 2014); several manipulation check items (e.g., items assessing the intensity of ostracism experienced by the participant during the most recent round of Cyberball); and items assessing intrapersonal needs (e.g., sense of belonging) posited to be threatened by ostracism (Williams, 1997). The mood scale with bipolar items, the manipulation check items, and the need threat items were based on questions used to assess Cyberball's impact by its developers (Williams et al., 2000; Zadro et al., 2004). **Table 2** contains additional information about the task-related questionnaires, including α values.

The "final" questionnaires included the DEBQ, which includes an Emotional Eating scale (12 items; e.g., "Do you have a desire to eat when you are depressed or discouraged?"). Responses are indicated on a 5-point scale ranging from "Never" (=1) to "Very Often" (=5). In our sample, $\alpha = 0.97$ for the DEBQ Emotional Eating scale.

The funnel debriefing interview (see **Supplementary Material Section 3**) was adapted from Lakin (2003). **Supplementary Material Section 4** presents information on interview response coding and awareness of critical aspects of the study.

Data Analysis

All analyses were conducted in R version 4.0.2. Planned analyses were specified *a priori*, and exploratory analysis were specified based on results of planned analyses.

Planned Analyses

To examine the effects of Cyberball condition (exclusion vs. inclusion) on self-report measures, we performed paired *t*-tests and calculated Hedges' g_{rm} as a measure of effect size (Lakens, 2013). We also performed Wilcoxon signed rank tests for paired samples, but did not report results because they were very similar to those of paired *t*-tests. To examine the effects of Cyberball condition on milkshake intake, we fitted two linear mixed effects models to the trial-level data using the nlme package for R: Model 1 examined the effect of exclusion (vs. inclusion) in the sample overall, and Model 2 examined how the effect of exclusion (vs. inclusion) differed based on DEBQ Emotional Eating scores. In all models, the outcome variable was milkshake intake (in g), centered around the participant-specific mean. Predictors in Model 1 were trial-level variables that might influence milkshake intake, including: indicators for the chocolate images that preceded milkshake intake; Trial and Trial^2, with Trial equal to the trial number minus 6.5; and an indicator for Condition (exclusion = 1; inclusion = 0). (We used AIC to compare linear, quadratic, and cubic parameterizations for Trial, which indicated that the quadratic model fit best.) Predictors in Model 2 included all Model 1 predictors, as well as a main effect for DEBQ Emotional Eating and its interaction with the indicator for Condition. Both models included a random intercept at the participant level.

Exploratory Analyses

Supplementary Material Section 5 presents information on exploratory analyses, as well as a description of questionnaires included in those analyses.

RESULTS

This section presents results from planned analyses, and **Supplementary Material Section 5** presents results of exploratory analyses.

Sample

For the 20 participants included in the analysis sample, the mean (SD) age was 23.1 (3.8) years. **Table 1** presents additional demographic and other information for these participants.

The 11 participants reporting high emotional eating at screening showed a substantial prevalence of lifetime major depressive disorder (54.5%) and eating disorders, with 27.3% meeting criteria for a current eating disorder and 45.5% meeting criteria for a past eating disorder. (One individual met criteria for both bulimia nervosa and binge-eating disorder at different points in the past.) In contrast, of the 9 participants reporting low emotional eating at screening, zero and 11.1% met criteria for a current or past eating disorder, respectively.

Effects of Cyberball Exclusion on Self-Report

In "task-related" questionnaires administered after the final exclusion and inclusion rounds of Cyberball, participants reported receiving a significantly smaller percentage of throws and feeling significantly more intense ostracism after exclusion, compared to inclusion (**Table 2**). Also, participants reported significantly greater threat to belongingness and to socially oriented self-esteem after exclusion, compared to inclusion; however, threat to meaningful existence and to control did not differ between exclusion and inclusion rounds. Effect sizes for percent throws, intensity of ostracism, threat to belongingness, and threat to self-esteem were large. Finally, although changes in affect were all in the expected direction (i.e., greater negative, and less positive, affect after the exclusion round), they were generally small and non-significant.

Milkshake Intake

On 4.2% of trials, milkshake intake could not be calculated due to missing values, or calculations produced impossible values of negative intake. **Figure 2** depicts the distribution of calculated milkshake intake values for each trial. Intake was markedly higher for the first trial and declined thereafter, and there was reduced variability for later trials.

Effect of Cyberball Exclusion on Milkshake Intake

Table 3 present results for linear mixed effects models. In Model 1, the main effect of Condition was −2.24 (95% CI [−4.76, 0.28]), which is in the direction of reduced milkshake intake after exclusion (vs. inclusion; see **Figure 3**), although the confidence interval includes small positive values. In Model 2, the interaction between Condition and DEBQ Emotional Eating was −1.11 (95% CI [−3.36, 1.13]), which is in the opposite direction as expected, although the confidence interval does include positive values. In both models, milkshake intake

TABLE 2 | Comparison of manipulation check, affect, and need threat variables between exclusion and inclusion rounds of Cyberball.[a]

Variable name (order in which completed)	Post-inclusion round			Post-exclusion round			Post-exclusion round vs. Post-inclusion round		
	α	Mean	SD	α	Mean	SD	Paired t-test t-statistic (p)		g_{rm}
Manipulation checks									
Percent Throws[b] (8)	–	50.9	17.2	–	20.3	24.8	−5.01	(<0.001)	−1.39
Intensity of Ostracism[c] (9)	0.94	3.3	1.7	0.89	6.4	2.1	6.11	(<0.001)	1.56
Affect									
Visual Analogue Mood[d] (1)	0.80	6.5	1.6	0.76	6.2	1.3	−0.98	(0.34)	−0.20
IPANAT Negative Affect[e] (6)	0.80	1.6	0.3	0.65	1.7	0.3	1.09	(0.29)	0.12
IPANAT Positive Affect[e] (6)	0.75	2.1	0.4	0.90	2.0	0.4	−2.73	(0.02)	−0.32
POMS-2-ASF Anger-Hostility[f] (7)	0.60	0.5	0.9	0.69	1.4	2.0	2.29	(0.04)	0.48
POMS-2-ASF Depression-Dejection[f] (7)	0.66	0.7	1.6	0.84	0.8	1.6	0.49	(0.63)	0.06
POMS-2-ASF Tension-Anxiety[f] (7)	0.84	1.7	2.5	0.75	1.9	2.3	0.36	(0.73)	0.06
POMS-2-ASF Vigor-Activity[f] (7)	0.80	6.8	3.3	0.86	6.0	4.0	−1.25	(0.23)	−0.20
Need Threat									
Need Threat Belongingness[g] (2)	–	3.0	1.5	–	6.7	1.8	6.79	(<0.001)	2.14
Need Threat Meaningful Existence[g] (3)	–	1.5	0.7	–	1.7	1.0	1.45	(0.17)	0.19
Need Threat Control[g] (4)	–	2.5	1.8	–	2.8	1.9	1.56	(0.14)	0.13
Need Threat Socially Oriented Self-Esteem[g] (5)	–	4.2	1.9	–	6.0	1.7	3.75	(<0.01)	1.01

IPANAT, Implicit Positive and Negative Affect Test; POMS-2-ASF, Profile of Mood States 2-Adult Short Form; SD, Standard deviation.

[a]After 12 rounds of the Cyberball-Milkshake Task, participants played a final exclusion round and a final exclusion round of Cyberball (order counterbalanced); immediately after each Cyberball round ended, participants completed questionnaires about their current mood and their recent experience of Cyberball.

[b]Following Zadro et al. (2004), Percent Throws was the response to one item ("What percent of the throws were thrown to you?"), which was allowed to range between 0 and 100. One participant was excluded from the statistics for percent throws due to item missingness.

[c]Following Williams et al. (2000), Intensity of Ostracism was calculated as the mean response to items that assessed the experience of ostracism (here, "Did you feel included by the other participants?" (reverse scored); "Did you feel ignored by the other participants?"; "Did you feel excluded by the other participants?") using a response scale ranging from 1 (Not at all) to 9 (Very much so). A higher mean response corresponds to experiencing more intense ostracism.

[d]Following Williams et al. (2000), the Visual Analogue Mood scale was calculated as the mean response to bipolar mood items (bad–good; happy–sad (reverse scored); tense–relaxed; rejected–accepted) using a response scale ranging from 1 (e.g., bad) to 9 (e.g., good). A higher mean response corresponds to a more positive mood.

[e]The IPANAT involves rating the degree to which six artificial words (e.g., VIKES) express three negative moods (helpless, tense, and inhibited) and three positive moods (happy, cheerful, and energetic), using response options ranging from "Does not fit at all" (=1) to "Fits very well" (=4). Scores for Negative Affect and Positive Affect are calculated by first averaging responses regarding each mood across the six artificial words, and then averaging the resulting mood scores across the three negative and three positive moods, respectively. One participant was excluded from the statistics for both Negative Affect and Positive Affect due to item missingness.

[f]Items from four POMS-2-ASF scales (Anger-Hostility; Depression-Dejection; Tension-Anxiety; Vigor-Activity) were administered. For each item, participants indicated the degree to which they were experiencing a particular feeling using response options including "Not at all" (=0), "A little" (=1), "Moderately" (=2), "Quite a bit" (=3), and "Extremely" (=4). Scores for each scale were calculated by summing responses to items belonging to that scale, with a higher score corresponding to greater endorsement of the relevant mood state.

[g]Similar to Williams et al. (2000), Need Threat was the response to items that assessed threat to certain intrapersonal needs posited to be threatened by ostracism (Belongingness: "How much do you feel you belonged to the group?" (reverse scored); Meaningful Existence: "How true is the statement: 'Life is meaningless'?"; Control: "How true is the statement: 'I am in control of my life'?" (reverse scored); Socially Oriented Self-Esteem: "To what extent do you think the other participants valued you as a person?" (reverse scored)) using a response scale ranging from 1 ("Not at all") to 9 ("Very much so"). Responses to certain items were reversed so that higher responses correspond to greater need threat.

decreased quadratically across trials, with a steep negative slope for low trial numbers that decreased to the point of being flat for the highest trial numbers.

DISCUSSION

We introduced the cyberball-milkshake task (CMT), which is designed to measure ostracism's impact on the consumption of highly palatable food. Our goal was to develop a task that would facilitate future investigations of individual differences in ostracism's effects on eating behavior, including potential neuroimaging investigations into the neural underpinnings of these effects (Sebastian et al., 2011). The resulting task could be used to investigate ostracism's effect on eating behavior in the general population. Additionally, given evidence that negative interpersonal experiences may precipitate eating disorder symptoms, such as binge-eating and restriction (Rieger et al., 2010), and that ostracism and rejection are especially negative interpersonal experiences (Baumeister et al., 2005; Williams, 2007), particularly for individuals with eating disorders (Cardi et al., 2013), the task might also prove useful for investigating how negative interpersonal experiences precipitate certain eating disorder symptoms (e.g., binge-eating and restriction) in samples with eating disorders. Additionally, the task could also be used in samples with eating disorders to examine whether current eating disorder interventions are efficacious at mitigating ostracism's effects on eating behavior. If feasible and valid, the task could fill an important gap since few studies have examined the impact of interpersonal stressors on actual eating behavior in eating disorders (Monteleone et al., 2018), despite the importance of rigorous and reproducible laboratory studies of eating behavior for advancing our understanding of eating behavior and eating disorders (Sysko et al., 2018).

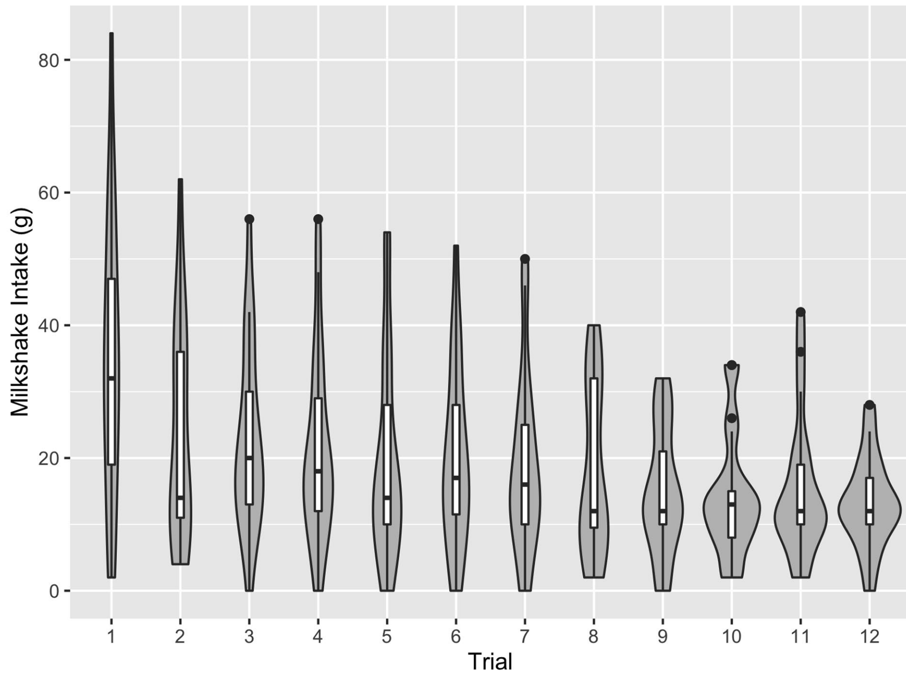

FIGURE 2 | Violin plots of milkshake intake, by trial. Violin plots reveal that median milkshake intake was highest during the first trial and generally decreased thereafter, with reduced variability in later trials.

TABLE 3 | Model fitting results for Cyberball-Milkshake Task (all trials).[a]

	Model 1[b]		Model 2[c]	
	Estimate	**95% CI**	**Estimate**	**95% CI**
Intercept	−3.17	[−7.75, 1.41]	−4.77	[−10.94, 1.40]
Chocolate Image: FP0289	−0.21	[−6.23, 5.81]	−0.16	[−6.20, 5.88]
Chocolate Image: FP0675	1.52	[−3.57, 6.61]	1.60	[−3.50, 6.71]
Chocolate Image: FP0703	3.12	[−2.01, 8.24]	3.14	[−2.00, 8.28]
Chocolate Image: FP0713	2.04	[−3.91, 7.99]	2.27	[−3.71, 8.25]
Chocolate Image: FP0083	0.78	[−5.16, 6.73]	0.94	[−5.03, 6.91]
Chocolate Image: FP0878	1.21	[−4.75, 7.17]	1.42	[−4.57, 7.41]
Chocolate Image: FP0879	4.68	[−1.29, 10.65]	5.19	[−0.88, 11.26]
Chocolate Image: IAPS7330	4.97	[−1.04, 10.98]	5.23	[−0.82, 11.27]
Chocolate Image: IAPS7340	5.12	[−0.80, 11.04]	5.39	[−0.57, 11.35]
Trial	−1.53	[−1.89, −1.17]	−1.52	[−1.89, −1.16]
$Trial^2$	0.17	[0.05, 0.29]	0.16	[0.04, 0.28]
Condition: Exclusion	−2.24	[−4.76, 0.28]	0.63	[−5.68, 6.94]
DEBQ EE	–	–	0.59	[−1.07, 2.26]
DEBQ EE × Condition: Exclusion	–	–	−1.11	[−3.36, 1.13]

CI, Confidence interval; DEBQ EE, Dutch Eating Behavior Questionnaire Emotional Eating; FP, FoodPics; IAPS, International Affective Picture System; SE, Standard error
[a]Outcome variable is milkshake intake in grams, centered based on subject-specific mean milkshake intake.
[b]Model 1 predictors include Chocolate Image (treated as a dummy coded categorical variable, with FP0167 as the reference category), Trial and $Trial^2$ (with Trial treated as a continuous variables and centered around 6.5), and Condition (treated as dummy coded categorical variable, with Inclusion as the reference category).
[c]Model 2 predictors include all Model 1 predictors, DEBQ EE (treated as a continuous variable), and DEBQ EE × Condition.

In the present study, we examined the feasibility of the CMT in a sample of individuals who reported very high or very low levels of emotional eating at screening. We also preliminarily examined the effects of ostracism on milkshake intake in the overall sample, and among individuals with varying levels of self-reported emotional eating. The following discussion focuses on results of planned analyses, except for a few instances (noted below) where we refer to results of exploratory analyses.

Regarding feasibility, exclusion during Cyberball generally had the intended effect, except for a potentially smaller-than-expected effect on affect. As expected, participants perceived receiving fewer throws during exclusion than inclusion, giving

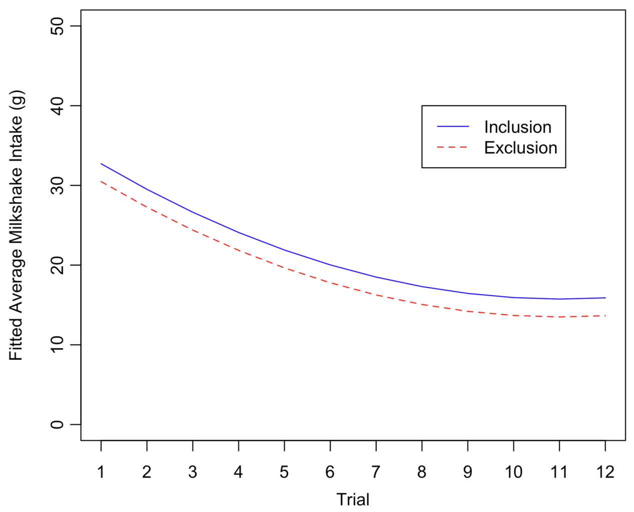

FIGURE 3 | Plot of fitted values of milkshake consumption versus trial number, by condition. Fitted values were calculated from the results of Model 1, for an average participant's chocolate milkshake intake and for an average chocolate image.

estimates comparable to prior studies using the modified version of Cyberball (Sebastian et al., 2011). Further, even after playing twelve prior rounds of Cyberball, exclusion during Cyberball led to greater feelings of ostracism and threatened psychological needs of belonging and socially oriented self-esteem, when compared to inclusion. Notably, prior research examining Cyberball's impact on the same need threat items also found that greater ostracism threatened belonging and self-esteem, but not control and meaningful existence (Williams et al., 2000). Finally, exclusion during Cyberball generally had small and non-significant effects on affect, whether assessed *via* implicit or explicit self-report measures. Importantly, some prior research (including a study with Cyberball) suggests that ostracism and rejection have limited effects on mood and that their effect on behavior, including eating behavior, is not mediated *via* changes in mood (Baumeister et al., 2005; Oaten et al., 2008). In contrast, a number of other studies have demonstrated higher levels of sadness and anger during Cyberball exclusion, at least as reported retrospectively (Williams, 2007). It is possible that exclusion would have had a greater impact on affect measured during Cyberball (rather than afterward), especially during an earlier trial of the task. It is also possible that Cyberball exclusion impacts affect only in certain subgroups (e.g., individuals high on rejection sensitivity), which our study was not powered to detect. Finally, our results and prior research (Baumeister et al., 2005) could also suggest another possibility, which is that negative interpersonal experiences are not necessarily accompanied by notable changes in subjective affect. If that is the case, increases in subjective negative affect may not fully mediate the link between negative interpersonal experiences and eating behavior, including eating disorder symptoms (Rieger et al., 2010).

Also regarding feasibility, milkshake intake was measurable for more than 95% of participants, and on more than 95% of the trials for those participants. Intake varied considerably across participants, especially in the earlier trials. Further, intake decreased sharply across initial trials and remained low and relatively constant across the final trials. This pattern raises the possibility that general or sensory-specific satiety affected intake during later trials. Future studies with the CMT should consider using fewer trials, and potentially excluding intake during the first trial from analysis, since it is markedly higher and potentially more influenced by factors not of interest, such as hunger.

Awareness checks (see **Supplementary Material Section 4**) revealed that between 40 and 65% of participants reported being aware during the CMT that the "other players" were not real, despite efforts to make participants believe they were playing against other study participants (see **Supplementary Material Section 2**). This number is higher than reported for other studies using Cyberball (Kelly et al., 2012). It is possible that our study design, specifically the repetition of shorter inclusion and exclusion rounds, may have increased participants' awareness that Cyberball was computerized or scripted (Best, 2010). However, this finding should be considered in light of research suggesting that Cyberball threatens psychological needs even when participants are aware they are playing against the computer or that the other players' behavior is scripted (Zadro et al., 2004), as well as research suggesting that Cyberball impacts physiological measures (e.g., skin conductance) even among "suspicious" participants (Kelly et al., 2012). In contrast, a minority of participants reported being aware that their milkshake intake was being measured, or that the CMT's aim was to assess the effect of ostracism on milkshake intake, during the CMT. These percentages compare favorably to similar laboratory studies (e.g., of emotional eating), where the majority of participants were aware that experimenters were assessing their food intake (Altheimer et al., 2021).

In our first model for milkshake intake, Cyberball exclusion was estimated to have a small negative effect on intake, although it is important to note that the 95% confidence interval for this effect included very small positive values. Prior research has sometimes, but not always, found greater intake of sweet food after Cyberball exclusion (Oaten et al., 2008; Hayman et al., 2015). However, there are certain methodological differences between this prior laboratory research and the CMT that could alter exclusion's effects on milkshake intake. For one, the CMT used shorter rounds of Cyberball, which may have had less of a potentiating effect on intake of highly palatable food. Additionally, in the CMT, the Milkshake Intake phase occurred seconds after the end of the Cyberball phase, rather than following an intervening questionnaire (Oaten et al., 2008); it may be that a longer delay between exclusion and milkshake intake, longer access to the milkshake, or being asked questions about the exclusion experience would allow greater reflection on the ostracism experience and result in greater consumption as a coping response (Hayman et al., 2015). Also, and not mutually exclusively, it is possible that, for some individuals, the immediate response to ostracism is reduced desire for highly palatable foods or an impulse to restrict one's intake of highly palatable foods.

In our second model for milkshake intake, Cyberball exclusion did not have the expected positive interaction with self-reported emotional eating, as measured by DEBQ Emotional Eating scores, although it is important to note that the 95% confidence interval for this interaction did include positive values. In evaluating these results, it is important to consider that our sample size was small, that there was some restriction of range due to the absence of participants with extremely high Emotional Eating scores, and that Cyberball exclusion had a relatively small impact on negative affect. However, even in the absence of these study features, current evidence suggests that self-reported emotional eating would be unlikely to strongly predict task performance. At the time the present study was planned (2015–2016), research suggested that very high and very low Emotional Eating scores predicted eating behavior (van Strien, 2010), although some researchers had already begun to question the validity of self-reported emotional eating (Evers et al., 2009; Domoff et al., 2014). Since then, additional evidence has accumulated to suggest that self-report measures of emotional eating may have limited validity (Bongers and Jansen, 2016; Evers et al., 2018; Altheimer et al., 2021).

Our study has several strengths, including a successful method of inducing ostracism and objective measurement of food intake. Further, our study adheres to many methodological best practices for laboratory studies of eating behavior (Robinson et al., 2018), including efforts to standardize pre-task food consumption, efforts at blinding participants to the measurement of food intake and study aims, and measurement of blinding success.

The study also has certain limitations that should be considered. First, the sample size was small, which limits confidence in results. Also, although we used a measure of effect size more appropriate to small samples, effect size may still have been overestimated (Lakens, 2013). Additionally, we did not correct for multiple comparisons (e.g., when examining the effect of exclusion on affect), although we took care not to interpret isolated significant or trend level results. However, the CMT did have six trials per condition for each participant, yielding higher power than a single instance of each condition per participant, or a between-participant design; additionally, our sample size was above the median for within-person studies of eating behavior (Robinson et al., 2018). Another limitation is that the sample was comprised of young adult women, and the majority of participants identified as White; these demographic groups are over-represented in eating disorder research, and future research should employ more diverse samples (Goel et al., 2022). Additionally, the CMT Cyberball phase was based on a modified version of Cyberball that contrasts exclusion with over-inclusion (as opposed to equal inclusion), to ensure that participants perceive the difference between conditions given the shorter rounds used in the modified version (Sebastian et al., 2011). Use of over-inclusion can complicate interpretation of differences (e.g., in milkshake intake) between conditions, raising the question of whether differences are due to the negative experience of exclusion or to the more positive experience of over-inclusion (De Waal-Andrews and Van Beest, 2020). Notably, in the present study, exploratory analyses found that individuals who reported being more sensitive to rejection also experienced greater threats to socially oriented self-esteem for exclusion minus inclusion (see **Supplementary Material Section 5**), suggesting that lower self-esteem after exclusion may be due at least in part to a detrimental effect of exclusion on self-esteem. However, this does not preclude effects of over-inclusion on psychological variables, such as self-esteem, or behavioral variables, such as milkshake intake. For example, over-inclusion could impact milkshake intake by inducing positive emotions, which have been shown to affect food intake (Cardi et al., 2015; Evers et al., 2018). Finally, the inclusion of a Chocolate Image phase between the Cyberball and Milkshake Intake phases of the CMT may have introduced extraneous variability into participants' milkshake intake, depending on how external food cues impacted their behavior.

These limitations notwithstanding, the present study suggests that the CMT is generally a feasible approach to examining how ostracism affects consumption of highly palatable food. The present study also suggests several ways in which future users of the CMT could consider modifying task design and analysis to potentially improve feasibility and validity. First, reducing the number of CMT trials may make it less likely that participants will habituate to the effects of Cyberball exclusion or begin to suspect that the game is computerized or scripted. Further, doing so may reduce the likelihood of general or sensory-specific satiety impacting milkshake intake. Additionally, given that milkshake intake on the first CMT trial appears to be markedly higher and is potentially more influenced by factors not of interest (e.g., hunger), it may be advisable to exclude the first trial from analysis. Second, users may wish to consider longer rounds of Cyberball, as in the more standard version of the game (Williams et al., 2000), since longer rounds may potentiate the experience of exclusion and lead to more marked effects of exclusion on milkshake intake. Longer rounds would also facilitate contrasting exclusion with (equal) inclusion, as opposed to over-inclusion, a third potential modification that would simplify interpretation of differences (e.g., in milkshake intake) for exclusion vs. inclusion. Fourth, omitting the Chocolate Image phase may reduce extraneous variability (e.g., due to the effects of food cues) on milkshake intake. Fifth, with regards to analysis of milkshake intake, Condition (i.e., exclusion vs. inclusion) could be allowed to interact with the high-order terms for trial number, rather than assuming that Condition has a constant effect on milkshake intake regardless of trial number.

Additionally, careful consideration should be given to how best to validate the CMT in future research. Although we used a questionnaire measure of emotional eating in response to general negative affect (specifically, the DEBQ Emotional Eating scale) to do so, this may not have been the best approach to validation, for multiple reasons. For one, ostracism may not induce marked changes in subjectively experienced emotions (Baumeister et al., 2005; Oaten et al., 2008), suggesting that measures of how individuals' food intake changes in response to ostracism, rather than in response to negative emotions, may better predict CMT performance. Additionally, questionnaire measures may not accurately capture how various factors (e.g., negative experiences) actually influence individual's eating behavior in the natural environment (Bongers and Jansen, 2016), suggesting it may be better to focus on comparing CMT performance to ecological momentary assessment of naturalistic behaviors, which may be subject to fewer biases (e.g., in recall) than questionnaires (Reichenberger et al., 2020). Further, more specific, as opposed to more general, measures may be more likely to predict behavior on the CMT (Sproesser et al., 2014), suggesting that CMT performance may be better predicted by measures focusing on changes in individuals' food intake in response to ostracism in particular, rather than in response to negative experiences more generally. Finally, measures that assess decreases as well as increases in actual food intake may be more likely to predict eating behavior on the CMT, compared to measures, such as the DEBQ Emotional Eating scale, that focus on assessing the *desire* to eat and that focus only on increases (Meule et al., 2018; Reichenberger et al., 2020). Given these reasons, our general recommendation would be to validate the CMT with respect to ecological momentary assessment focused on measuring the association between interpersonal stressors (or potentially ostracism in particular) and intake of highly palatable food in the natural environment (O'Connor et al., 2008). Additionally, if the CMT were to be validated with respect to a questionnaire measure, our recommendation would be to use a measure of restrained eating (Reichenberger et al., 2020), which has been shown to predict behavior in response to negative experiences in experimental studies (Evers et al., 2018). If the CMT were to be validated with respect to a questionnaire-based measure of emotional eating, our recommendation would be to use the Salzburg Emotional Eating Scale (Meule et al., 2018), which assesses changes in food intake, including reduced intake, in response to specific emotions. Notably, in our exploratory analyses of CMT Trials 2 through 7 (see **Supplementary Material Section 5**), individuals who reported eating less in response to anxiety (on the Anxiety subscale of a modified Emotional Eating Scale) demonstrated reduced milkshake intake following exclusion, whereas individuals who reported eating more in response to anxiety demonstrated increased milkshake intake following exclusion.

Finally, regarding sample considerations, future research should investigate the CMT in a considerably larger sample that includes individuals with and without eating disorders (Reichenberger et al., 2020).

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by MassGeneral Brigham Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

KNJ conceived, designed the study, and performed the statistical analysis and wrote the first draft of the manuscript. HGP, JIH, SAG, and SFG contributed to the design of the study. KNJ, EML, LLP, MER, and CP acquired the data for the study. All authors contributed to manuscript revision and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.853555/full#supplementary-material

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The Association Between Plant-Based Diet Indices and Obesity and Metabolic Diseases in Chinese Adults: Longitudinal Analyses From the China Health and Nutrition Survey

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Background: A wide range of health benefits are associated with consuming a diet high in plant-based foods. Diet quality can be accurately assessed using plant-based diet indices, however there is inadequate evidence that plant-based diet indices are linked to obesity, hypertension, and type 2 diabetes (T2D), especially in Chinese cultures who have traditionally consumed plant-rich foods.

Methods: The data came from the China Nutrition and Health Survey. Overall, 11,580 adult participants were enrolled between 2004 and 2006 and followed up until 2009 or 2015 (follow-up rate: 73.4%). Dietary intake was assessed across three 24-h recalls, and two plant-based dietary indices [overall plant-based diet indice (PDI) and healthy plant-based diet indice (hPDI)] were calculated using China Food Composition Code and categorized into quintiles. The study's endpoints were overweight/obesity, hypertension, and T2D. The Hazard ratio (HR) and dose-response relationship were assessed using the Cox proportional risk model and restricted cubic splines. The areas under the curve of the receiver operating characteristic curve analyses were used to evaluate the predictive performance of the PDI and hPDI.

Results: During the median follow-up period of more than 10 years, 1,270 (33.4%), 1,509 (31.6%), and 720 (11.5%) participants developed overweight / obesity, hypertension, and T2D, respectively. The higher PDI score was linked with a reduced risk of overweight/obesity [HR: 0.71 (95% CI: 0.55–0.93), *P*-trend $<$0.001], hypertension [HR: 0.63 (95% CI: 0.51–0.79), *P*-trend $<$0.001], and T2D [HR: 0.79 (95% CI: 0.72–0.87), *P*-trend $<$0.001]. The hPDI score was inversely associated with overweight/obesity [HR: 0.79 (95% CI: 0.62–0.98), *P*-trend = 0.02] and T2D [HR: 0.84 (95% CI: 0.75–0.93), *P*-trend = 0.001]. In the aged $<$55-year-old group, subgroup analysis indicated a significant negative association between PDI/hPDI and overweight/obesity, hypertension, and T2D. There was no significant difference in the areas under the curve of the fully adjusted obesity, hypertension, and diabetes prediction models between PDI and hPDI.

Conclusion: The PDI and hPDI scores were very similar in application in Chinese populations, and our findings highlight that adherence to overall plant-based diet index helps to reduce the risk of T2D, obesity, and hypertension in Chinese adults who habitually consume plant-based foods, especially for those aged <55 year. Further understanding of how plant-based diet quality is associated with chronic disease will be needed in the future, which will help develop dietary strategies to prevent diabetes, hypertension, and related chronic diseases.

Keywords: obesity and metabolic diseases, longitudinal analyses, China Health and Nutrition Survey, healthy plant-based diet index, plant-based diet index

INTRODUCTION

The prevalence of obesity, type 2 diabetes (T2D), and hypertension, which are three key risk factors for cardiovascular disease, is increasing globally. It is estimated that T2D affects more than 370 million people and uncontrolled hypertension more than 970 million people worldwide (1), while the global prevalence of overweight and obesity has increased from 20% in 1975 to 40% in 2016 (2). Obesity, T2D, and hypertension constitute the leading causes of death from non-communicable diseases.

The Global Burden of Disease study identified diet as a major modifiable risk factor for non-communicable diseases morbidity and mortality (3). Food group analyses are easier to interpret and translate into recommendations for the primary prevention of obesity, hypertension, and T2D than those of nutrients or complex dietary patterns. Most studies have focused on whether high adherence to plant-based diets and restricted animal diets is associated with poor health outcomes, finding that individuals on vegetarian diets have good metabolic profiles [e.g., lower body mass index (BMI), lower blood pressure, and lower fasting glucose] (4–7). However, extreme dietary changes (e.g., the complete exclusion of animal-based foods) may be difficult to adopt and adhere to over the long term when translating research findings into public health and clinical applications. Moreover, different plant foods are associated with different health outcomes. In particular, less nutrient-dense plant foods (e.g., sugary drinks and salt) are associated with a higher risk of obesity, T2D, and hypertension.

In this context, "plant-based diet indices" (PDIs), which assess the degree of dietary adherence in higher plant-based foods and lower animal-based foods, form a new indicator that has recently been introduced. The "healthy plant-based diet index" (hPDI) measures higher adherence to healthy plant-based foods (e.g., fruits, vegetables, whole grains, nuts, legumes, tea, and coffee) and lower adherence to unhealthy plant-based foods (e.g., refined grains and high-sugar foods) and animal-based foods.

A few studies have used PDIs to assess plant food and animal food intake and considered the health status of plant foods. These studies have focused on hypertension (8), diabetes mellitus (9), weight change (10), chronic kidney disease (11), and metabolic syndrome (12). However, evidence on the association between PDIs and the risk of obesity, hypertension, and T2D is still scant. More importantly, these studies have been performed mainly in Western adult populations living in developed countries (i.e., the United States and Europe). Only two prospective studies on PDIs have been conducted in Asian populations (12, 13). Considering the heterogeneity found in the quantity and quality of diets in different populations and its effects on the health statuses (14, 15), these associations may require further analysis in Asian populations that traditionally consume diets rich in plant foods.

The aim of this study was to assess the association between the PDI and the hPDI and overweight/obesity, hypertension, and T2D using data from the China Health and Nutrition Survey (CHNS).

MATERIALS AND METHODS

Study Design and Participants

The CHNS is an open, prospective, population-based, longitudinal study (16) that aims to explore the impact of the socio-economic transformation of Chinese society on the nutritional and health status of the Chinese population. Launched in 1989 and followed up on in 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, and 2015, the CHNS uses a multi-stage random sampling strategy to draw samples from 15 provinces with different demographic, geographic, economic, and public resources (17). The scientific rationale and design of the CHNS have been reported previously (18). Adult participants in the 2004 and 2006 surveys were included in this report because the China Food Composition Code (2002/2004 edition) began to be used in 2004(19, 20), and we used the 2015 survey as the primary study endpoint time, while the diabetes outcome assessment also considered the 2009 glucose/glycated hemoglobin (HbA1c) index. The Institutional Review Board of the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Health of the Chinese Center for Disease Control and Prevention approved the investigation (No. 201524). All participants gave their informed consent before the study. This study is reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

From the total number of adult participants at baseline ($n = 11,774$), we excluded 26 with extremely low or high total energy intakes (<500 kcal/day or >5,000 kcal/day, respectively) and 168 participants with cardiovascular disease (i.e., myocardial infarction, stroke, or angina) or cancer because a diagnosis of chronic disease may prompt individuals to change their dietary behavior. A total of 8,503 individuals were tracked to 2009 or 2015 (follow-up rate: 73.4%). We excluded 3,778, 3,681, and 327 participants who were overweight or had obesity, had hypertension, and had diabetes at baseline, respectively. Finally, we excluded 4,007 overweight/obese, 3,124 hypertensives, and 3,042 diabetic individuals with missing outcomes, respectively. In the final analysis sample, a total of 3,795 individuals in Sample 1 were used to study the association between PDIs and overweight/obesity, a total of 4,775 individuals in Sample 2 were used to study the association between PDIs and hypertension, and a total of 8,211 individuals in Sample 3 were used to study the association between PDIs and T2D (**Figure 1**).

Dietary Assessment

At the time of the baseline (2004 or 2006) survey, dietary assessment in the CHNS was performed by trained researchers during the same period (2 weekdays and 1 weekend day) utilizing three consecutive 24-h individual-level food recalls and household-level food inventory weighing (see **Supplementary S1 Text for the Dietary Questionnaire**). Detailed information on the dietary assessment has been previously published (18). In brief, all available food (purchased, stored, or home produced) was weighed daily on a digital scale (minimum 1 g, maximum 3 kg). Household food consumption is estimated by examining the changes in household food stocks and waste. With the help of the food model, individual dietary intake was estimated by asking each household member to report the type, quantity, time, and place of consumption of all foods consumed at home and outside of the home the previous day. For each dish prepared at home, the amount of food consumed by each individual was estimated based on the ratio of household food consumption to individual consumption. If there were significant differences in food consumption at the household level and individual level, the interviewer returned to the household and the individual in question to record further details regarding the individual's food consumption. Dietary intake of cereals, meat, vegetables, and fruits was estimated for each individual based on the mean of three 24-h dietary recalls.

To ensure the stability of the dietary data, we used average year data for 2004 and 2006 as the baseline dietary assessment. When participants participated in only one of the survey years, the current year's dietary intake could be utilized as the baseline assessment.

We calculated two plant-based diet indices (PDI, hPDI) based on average 24-h dietary assessment data. The calculation of each dietary index and the differences between the indices have been described in detail in previous studies (8, 9, 12). Briefly, referring to the China Food Composition Code (2002/2004 edition) and the classification of food items in the aforementioned studies, all foods were classified into 17 food groups (**Supplementary Table S1**) in this study. These food groups were classified as healthy plant foods (whole grains, fruits, vegetables, nuts, legumes, tea and coffee, and vegetable oils), less healthy plant foods (refined grains, potatoes, sugary drinks, sweets and desserts, and preserved foods), and animal foods (animal fats, dairy products, eggs, fish or seafood, and meat). Considering the specificity of the Chinese diet, we added the category "fermented foods" and deleted the category "miscellaneous animal foods" (considering that almost none of our subjects reported consuming them).

Considering that residuals were independent of food consumption, this study adjusted for total energy intake by using the residual method and ranked participants by quintile for each food group (21) to give a positive or a negative score. For the PDI, all plant foods were scored positively; for the hPDI, only healthy plant foods were scored positively. For a positive score, individuals in the fifth quartile scored five points and individuals in the first quartile scored one point. For negative scores, individuals in the fifth quartile scored one point and individuals in the first quartile scored five points. The scores of 17 food groups for each participant were then summed to obtain a theoretical range of indices ranging from 17 to 85, and the overall index was divided into quintiles for analysis (22), with higher quartiles representing better adherence.

Measurement

A structured questionnaire was used to collect participant information including demographic characteristics (age, gender, and education), lifestyle (total energy intake, physical activity, smoking status, and alcohol intake), general health status (diabetes and hypertension), and disease history (myocardial infarction, stroke, angina, and cancer). Participants were asked to wear only light clothing and no shoes when measuring their height and weight and to measure their height to the nearest 0.1 cm using a SECA tape measure and measure their weight to the nearest 0.1 kg using a calibrated balance scale: body mass index (BMI) (kg/m^2) = weight (kg)/height $(m)^2$. Waist circumference was measured using a SECA tape measure at the narrowest point between the lowest rib of the ilium and the uppermost margin to the nearest 0.1 cm. After 5 min of sedation, blood pressure was monitored using a mercury sphygmomanometer on three consecutive occasions, each 3–5 min apart, and the mean of the three systolic and diastolic blood pressure measurements was counted in the analysis.

Blood samples for 2009 were collected according to strict quality control standards specifications, and after a minimum 12-h overnight fast, blood samples (12 mL) were collected by venipuncture in the morning and transferred to a local hospital for processing within 2 h of collection. All blood samples were analyzed at the Beijing National Central Laboratory (Medical Laboratory Accreditation Certificate: ISO 15189:2007) (23). Fasting glucose determination and routine blood tests were performed at the local hospital using the glucose oxidase-phenol and 4-amino benzoquinone method (Randox Laboratories Ltd., Crumlin, Co. Antrim, UK). HbA1c was determined by high-performance liquid chromatography (HLC-723 G7 analyzer; Tosoh Corp., Tokyo, Japan).

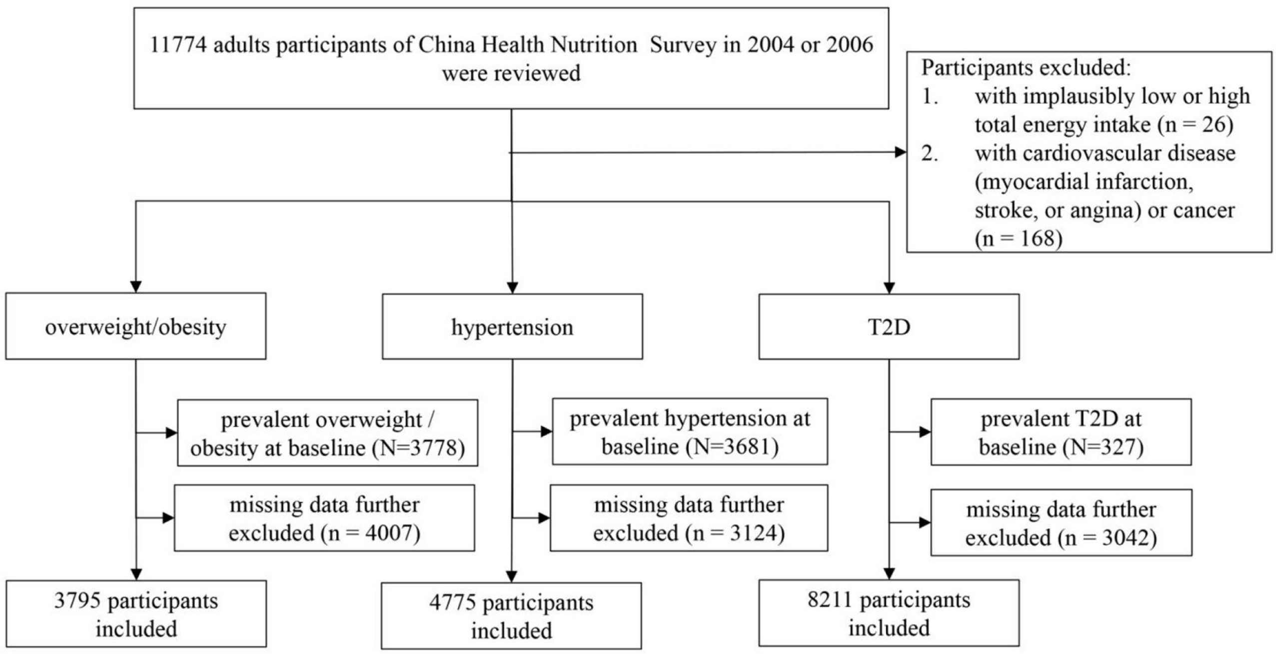

FIGURE 1 | Participant flow diagram.

Assessment of Covariates

We classified education levels into four categories: elementary school and below, middle school, high school, and college and above. We calculated the daily metabolic equivalent task for each participant by calculating the type and intensity of physical activity (24). Smokers were defined as subjects who smoked an average of one or more cigarettes per day for at least 6 months before the survey and were still smoking in the 1 month before the survey; other subjects were categorized as non-smokers. Alcohol drinkers were defined as those who consumed beer, liquor, or other alcoholic beverages during the past year; other subjects were classified as non-drinkers. The model was adjusted for age, total energy intake, physical activity, and BMI as continuous variables.

Ascertainment of Overweight/Obesity, Hypertension, and T2D

Based on the overweight and obesity criteria recommended by the Chinese Working Group on Obesity, this study defined overweight/obesity as BMI $\geq$24 kg/m^2 (25, 26).

In the CHNS, questions about hypertension were asked as follows: (1) "Has a doctor told you that you have hypertension?" If so, (2) "How many years have you had hypertension?" and (3) "Do you take antihypertensive medication?" hypertension was defined as meeting at least one of the following criteria: (1) systolic blood pressure $\geq$140 mmHg, (2) diastolic blood pressure $\geq$90 mmHg, or (3) self-reported as having been diagnosed with hypertension or being on oral antihypertensive medication during follow-up (27).

In the CHNS, the following questions were asked about diabetes: (1) "Has a doctor told you that you have diabetes?" If so, (2) "How old were you when the diabetic disease was diagnosed?" and (3) "Have you had any of the following treatments, such as special diet, weight control, oral medication, insulin injections, herbal medicine, home remedies, qigong, etc.?" Based on the diagnostic criteria of the American Diabetes Association (28), T2D was defined as meeting at least one of the following criteria in the 2009 survey: (1) fasting blood glucose concentration of $\geq$7.0 mmol/L (126 mg/dL), (2) HbA1c $\geq$6.5%, or (3) self-reported diagnosis of T2D or on hypoglycemic medication. In 2015, it was defined based on self-reported diabetes or taking hypoglycemic medication. Previous studies have demonstrated that self-reported diabetes is a relatively valid tool for obtaining the diabetes status of Chinese study participants (29).

Statistical Analyses

Descriptive analyses were reported as the mean $\pm$ standard deviation (SD) or median (interquartile range), estimated as the mean $\pm$ SD for continuous variables and frequency (percentage) for categorical variables. Statistical differences in disease occurrence between groups were tested by analysis of variance, the Kruskal–Wallis test, or the chi-square test, respectively.

Following the methodological approach of the database (30), we used Spearman correlation analysis to explore the relationship between baseline PDI and hPDI. We used Cox proportional hazards models to estimate the association between PDIs and overweight/obesity, hypertension, and diabetes mellitus. The time indicator was the duration of follow-up from baseline

(2004 or 2006) to disease onset or the cut-off date. Time-dependent covariates analysis validated the assumption of equal proportional risk. Multiple covariates were selected and adjusted in the three models. In model 1, we adjusted for urban–rural, age, sex, and total energy intake. In model 2, we further adjusted for educational level, physical activity, smoking, and drinking. In model 3, we made additional adjustments for BMI. To test for potential non-linear associations, we tested for linear trends using the median score per quantile of index scores. By using index scores as continuous variables, we estimated the risk of disease for each standard deviation (1 SD) increase in each dietary index and also fitted restrictive cubic splines to the fully adjusted model to further observe the association between plant-based dietary indices and disease. The areas under the curve (AUC) of the receiver operating characteristic curve (ROC) analyses were used to evaluate the predictive performance of the PDI and hPDI. Since some studies have shown that age and sex (31, 32) associations between diet and disease may differ, we further stratified the results by sex and age and investigated whether the PDIs were associated with different sex and age groups. All statistical tests were two-sided and performed using SAS 9.4 (SAS Institute, Cary, NC) and R-4.1.2 (http://www.R-project.org/); $p < 0.05$ was considered statistically significant.

RESULTS

Characteristics of Participants

During a median follow-up of 10.76 years (total person-years: 40,845), 1,270 (33.4%) participants became overweight/developed obesity with a mean age of 44.01 ± 12.43 years. During a median follow-up of 10.28 years (total person-years: 49,127), 1,509 (31.6%) participants developed hypertension with a mean age of 48.79 ± 11.55 years. During a median follow-up of 10.18 years (total person-years: 83,633), 720 (8.7%) participants developed T2D with a mean age of 53.58 ± 12.14 years. In the disease prevalence overlap, 83 (11.5%) participants with T2D also suffered from being overweight/obesity, and 374 (24.8%) participants with hypertension also suffered from being overweight/obesity. In addition, 149 (1.8%) participants had both T2D and hypertension, and 28 (0.3%) participants had all three diseases simultaneously.

Comparisons of baseline characteristics between those who did and did not develop T2D, hypertension, and overweight/obesity are shown in **Table 1**. Age, BMI, waist circumference, and blood pressure significantly affect the incidence of all diseases. In addition, education and drinking affect the incidence of diabetes. Total energy intake and animal food intake affect the incidence of obesity. Hypertension has the most influencing factors; in addition to common factors, it also includes urban and rural areas, less healthy plant foods, animal foods, smoking, drinking, and education level.

In the present study, PDI and hPDI showed the highest Spearman correlation for overweight or obesity ($\rho = 0.76$), and Spearman correlation coefficients were 0.72 and 0.73 for T2D and hypertension.

Food Characteristics

In the overweight/obesity, hypertensive, and T2D populations, the highest quintile of PDI and hPDI had higher intakes of fruits, vegetables, nuts, legumes, potatoes, and salty foods and lower total intakes of meat (**Supplementary Table S3**). In the PDI, the highest quintile consumed on average 118–130 g of fruit and 377–380 g of vegetables per day, while the lowest quintile consumed on average 9.9–10.2 g of fruit and 320–362 g of vegetables per day. The highest quintile in the hPDI consumed on average 111.2–137.0 g of fruit and 348.9–375.1 g of vegetables per day, while in the lowest quintile, 5.2–7.5 g of fruit and 353.4–358.7 g of vegetables per day were consumed.

Risk of Overweight/Obesity by Baseline PDI and hPDI Quartiles

Table 2 indicates the incidence of overweight/obesity for individuals stratified by baseline PDI and hPDI quintiles. The trend in the incidence of overweight/obesity across increasing PDI and hPDI quintiles was highly statistically significant for all models ($p < 0.05$). In the multivariate models, the adjusted Hazard ratios (HR) was attenuated but remained significant in the comparison of the highest (Q5) and lowest (Q1) quartiles. When the PDI was modeled consecutively, the risk of overweight/obesity was reduced by 11% for every 1 SD increase in the index, which was statistically significant (95% CI: 0.82–0.97; *p*-trend < 0.001). When hPDI was assessed consecutively, there was a statistically significant difference of a 4% reduction in the risk of overweight/obesity occurrence for every 1 SD increase in the index (95% CI: 0.89–1.00; *p*-trend = 0.02). However, the restricted cubic spline of the association between PDI/hPDI and the risk of occurrence of overweight/obesity showed a U-shaped trend of decreasing and then gradually increasing the risk of overweight/obesity with increasing PDI/hPDI (**Figure 2**). The full adjustment overweight/obesity prediction model yielded an AUC of 0.784 (95% CI: 0.764–0.804) for PDI and 0.783 (95% CI: 0.763–0.803) for hPDI, with no significant difference ($p = 0.299$) (**Figure 3A**).

Risk of Hypertension by Baseline PDI and hPDI Quartiles

A higher PDI score was also associated with a reduced risk of developing future hypertension (**Table 2**). After adjusting for multiple potential covariates, participants in the highest PDI quartile had a 37% lower risk of developing hypertension (HR: 0.63, 95% CI: 0.51–0.79). The linear trend for increasing PDI quartiles remained highly significant in the multivariate model (*p*-trend < 0.001). When the PDI was assessed consecutively, the risk of hypertension was reduced by 12% (95% CI: 0.82–0.94; *p*-trend < 0.001) for every 1 SD increase in the index. There was a strong linear association between a higher PDI score and the incidence of hypertension (**Figure 2**).

In each hPDI model, no linear trend ($p > 0.05$) was detected in the risk of hypertension development in each quartile of hPDI. In multivariate models, adjusted HRs were all <1, but there was no statistical difference in the highest quartile (Q5) compared with the lowest quartile (Q1). However, when modeling the hPDI

TABLE 1 | Baseline characteristics of cohort by incident overweight/obesity, T2DM, or hypertension.

Characteristics*	No overweight/obesity	New overweight/obesity	*p*	No hypertension	New hypertension	*p*	No T2DM	New T2DM	*p*
Number	2,525	1,270		3,266	1,509		8,211	720	
Age (years)	46.3 ± 13.4	44.0 ± 12.4	<0.001	42.4 ± 12.7	48.7 ± 11.5	<0.001	46.1 ± 14.2	53.5 ± 12.1	<0.001
Male, *n* (%)	1,185 (47.4)	623 (49.5)	0.21	1,495 (46.1)	730 (48.6)	0.09	3,594 (48.3)	366 (50.2)	0.29
Rural, *n* (%)	1,848 (73.2)	945(74.4)	0.42	2,320 (71.0)	1,152 (76.3)	<0.001	5,185 (69.3)	491 (67.1)	0.22
Total energy intake (kcal/day)	2231.6 ± 597.3	2271.1 ± 653.2	0.03	2,244.3 ± 605.1	2259.1 ± 642.2	0.44	2,203.0 ± 571.2	2214.2 ± 640.7	0.56
Educational level, *n* (%)			0.09			<0.001			<0.001
Primary school or below	1,154 (46.2)	541 (43.1)		1,321 (40.7)	732 (48.8)		3,284 (44.1)	384 (52.7)	
Junior high school	851 (34.1)	458 (36.5)		1,196 (36.9)	489 (32.6)		2,468 (33.2)	188 (25.8)	
Senior high school	299 (11.9)	172 (13.7)		435 (13.4)	186 (12.4)		979 (13.1)	87 (11.9)	
College and above	194 (7.7)	85 (6.8)		292 (9.0)	93 (6.2)		700 (9.4)	69 (9.4)	
Physical activity (MET/day)	184.6 ± 124.2	192.3 ± 127.8	0.15	185.7 ± 124.5	181.0 ± 128.7	0.33	180.6 ± 125.1	173.2 ± 126.1	0.28
Smoking, *n* (%)	868 (34.7)	416(33.1)	0.31	1,010 (31.1)	519 (34.6)	0.01	2,437 (32.7)	253 (34.8)	0.24
Alcohol drinking, *n* (%)	840 (33.6)	429 (34.1)	0.71	1,028 (31.6)	552 (36.7)	<0.001	2,462 (33.1)	271 (37.2)	0.02
BMI (kg/m^2)	20.9 ± 1.9	22.8 ± 2.1	<0.001	22.3 ± 2.9	23.6 ± 3.3	<0.001	22.86 ± 3.2	25.3 ± 3.7	<0.001
Systolic BP (mm Hg)	117.4 ± 15.7	118.9 ± 16.4	0.01	114.0 ± 12.2	121.9 ± 13.6	<0.001	120.5 ± 17.3	130.1 ± 20.3	<0.001
Diastolic BP (mm Hg)	75.9 ± 10.2	77.9 ± 10.8	<0.001	74.6 ± 8.6	79.0 ± 9.1	<0.001	78.1 ± 10.7	82.7 ± 12.1	<0.001
Waist circumference (cm)	75.4 ± 7.6	80.3 ± 7.8	<0.001	78.3 ± 8.9	82.3 ± 9.4	<0.001	80.2 ± 9.5	87.3 ± 10.1	<0.001
Food groups									
Healthy plant foods (g/day)	540.0 ± 245.7	546.8 ± 274.8	0.41	546.1 ± 265.3	551.9 ± 266.0	0.48	564.8 ± 273.2	547.1 ± 252.8	0.22
Less-healthy plant foods (g/day)	433.2 ± 179.8	435.8 ±200.7	0.64	435.9 ± 191.2	423.2 ± 195.8	0.03	418.7 ± 187.4	426.5 ± 183.8	0.20
Animal foods (g/day)	169.7 ± 131.0	154.3 ± 129.7	<0.001	168.0 ± 131.9	156.2 ± 128.2	<0.001	173.9 ± 126.1	176.2 ± 138.3	0.41
Overall plant-based diet indice	19.3 ± 5.9	18.4 ± 5.7	<0.001	19.4 ± 6.1	18.7 ± 5.8	<0.001	20.2 ± 6.1	19.9 ± 6.1	0.15
Healthy plant-based diet indice	23.4 ± 14.8	23.2 ± 15.7	0.54	19.0 ± 6.9	18.7 ± 6.8	0.17	20.3 ± 7.1	19.7 ± 7.0	0.04

**Descriptive analyses of continuous variables were analyzed by means ± Standard deviations (SD) or medians (interquartile range) were estimated mean ± SD, and categorical variables were described by number (percentage). Analysis of variance (ANOVA) or Kruskal–Wallis test was used for continuous variables, and chi square test was used for categorical variables. BMI, body mass index; BP, blood pressure.*

TABLE 2 | Prospective associations between plant-based diet indices and incident overweight/obesity, hypertension and type 2 diabetes mellitus[a].

Incident overweight/obesity (*N* = 3,795)

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	P-trend	HR (95%) per 1 SD increase
PDI							
Number of cases	253	342	250	233	192		
Person-years	7,024	10,183	8,027	8,048	7,563		
Incidence density (1,000 person-year)	36.0	33.6	31.1	29.0	25.4		
Model 1	Ref	0.87 (0.74, 1.03)	0.81 (0.68, 0.95)	0.72 (0.61, 0.87)	0.62 (0.61, 0.76)	<0.001	0.85 (0.81, 0.90)
Model 2	Ref	0.83 (0.68, 1.01)	0.77 (0.62, 0.96)	0.65 (0.51, 0.81)	0.59 (0.46, 0.74)	<0.001	0.84 (0.78, 0.90)
Model 3	Ref	0.94 (0.76, 1.18)	0.89 (0.70, 1.11)	0.78 (0.61, 1.01)	0.71 (0.55, 0.93)	<0.001	0.89 (0.82, 0.97)
hPDI							
Number of cases	290	272	227	234	247		
Person-years	8,049	8,434	7,914	8,174	82,74		
Incidence density (1,000 person-year)	36.0	32.3	28.7	28.6	29.9		
Model 1	Ref	0.98 (0.75, 1.07)	0.77 (0.65, 0.92)	0.77 (0.65, 0.92)	0.75 (0.63, 0.89)	<0.001	0.94 (0.89, 1.00)
Model 2	Ref	0.89 (0.72, 1.09)	0.66 (0.53, 0.84)	0.72 (0.58, 0.89)	0.71 (0.57, 0.88)	<0.001	0.94 (0.87, 1.01)
Model 3	Ref	0.94 (0.75, 1.18)	0.76 (0.58, 0.98)	0.79 (0.63, 1.00)	0.79 (0.62, 0.98)	0.02	0.96 (0.89, 1.00)

Incident hypertension (*N* = 47,75)

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	P-trend	HR (95%) per 1 SD increase
PDI							
Number of events	382	297	268	322	240		
Person-years	106,88	9,447	9,371	10,036	9,585		
Incidence density (1,000 person, year)	35.7	31.4	28.6	32.1	25.0		
Model 1	Ref	0.84 (0.72, 0.97)	0.76 (0.65, 0.89)	0.87 (0.75, 1.01)	0.68 (0.58, 1.81)	<0.001	0.89 (0.84, 0.94)
Model 2	Ref	0.81 (0.66, 0.98)	0.70 (0.57, 0.86)	0.85 (0.70, 1.02)	0.61 (0.49, 0.75)	<0.001	0.86 (0.81, 0.93)
Model 3	Ref	0.83 (0.67, 1.00)	0.73 (0.59, 0.90)	0.91 (0.74, 1.10)	0.63 (0.51, 0.79)	<0.001	0.88 (0.82, 0.94)
hPDI							
Number of cases	349	340	255	320	245		
Person-years	10,945	11,101	8,352	10,190	8,539		
Incidence density (1,000 person-year)	31.9	30.6	30.5	31.4	28.7		
Model 1	Ref	0.95 (0.82, 1.11)	0.94 (0.80, 1.06)	0.96 (0.83, 1.12)	0.89 (0.76, 1.05)	0.26	0.95 (0.91, 1.01)
Model 2	Ref	1.04 (0.87, 1.26)	0.99 (0.81, 1.22)	0.93 (0.76, 1.14)	0.84 (0.67, 1.04)	0.07	0.93 (0.86, 0.99)
Model 3	Ref	1.04 (0.86, 1.27)	1.08 (0.87, 1.33)	0.95 (0.78, 1.17)	0.83 (0.66, 1.04)	0.09	0.93 (0.87, 1.00)

(Continued)

TABLE 2 | Continued

Incident Type 2 diabetes (N = 8211)	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	P-trend	HR (95%) per 1 SD increase
PDI							
Number of cases	149	170	143	137	121		
Person, years	16,140	19,501	16,351	16,013	15,628		
Incidence density (1,000 person-year)	9.2	8.7	8.7	8.6	7.7		
Model 1	Ref	0.81 (0.66, 0.98)	0.70 (0.57, 0.86)	0.85 (0.70, 1.02)	0.61 (0.49, 0.75)	<0.001	0.93 (0.91, 0.95)
Model 2	Ref	0.89 (0.81, 0.98)	0.86 (0.78, 0.95)	0.85 (0.77, 0.94)	0.80 (0.72, 0.88)	<0.001	0.93 (0.90, 0.96)
Model 3	Ref	0.89 (0.81, 0.98)	0.87 (0.78, 1.45)	0.85 (0.76, 0.93)	0.79 (0.72, 0.87)	<0.001	0.93 (0.90, 0.96)
hPDI							
Number of cases	156	133	160	165	106		
Person-years	15,803	15,431	18,367	17,164	16,868		
Incidence density (1,000 person-year)	9.9	8.6	8.7	9.6	6.3		
Model 1	Ref	0.96 (0.89–1.03)	0.93 (0.87–1.00)	0.91 (0.84–1.00)	0.91 (0.84–0.98)	<0.001	0.95 (0.93, 0.97)
Model 2	Ref	0.94 (0.86–1.04)	0.91 (0.82–0.99)	0.90 (0.82–0.99)	0.84 (0.76–0.93)	<0.001	0.94 (0.91, 0.97)
Model 3	Ref	0.94 (0.85–1.03)	0.90 (0.81–0.99)	0.90 (0.81–0.99)	0.84 (0.75–0.93)	0.001	0.94 (0.92, 0.98)

Model 1 was adjusted for age, urban and rural, sex, and total energy intake. Model 2 was adjusted for age, urban and rural, sex, total energy intake, education, physical activity, smoking status, and alcohol drinking. Model 3 was adjusted for age, sex, total energy intake, education, physical activity, smoking status, alcohol drinking, baseline systolic and diastolic blood pressure, and BMI.

[a] *The quintiles do not have equal sample size because many participants received the same scores.*

BMI, body mass index; PDI, overall plant-based diet index; hPDI, healthful plant-based diet index; SD, standard deviation.

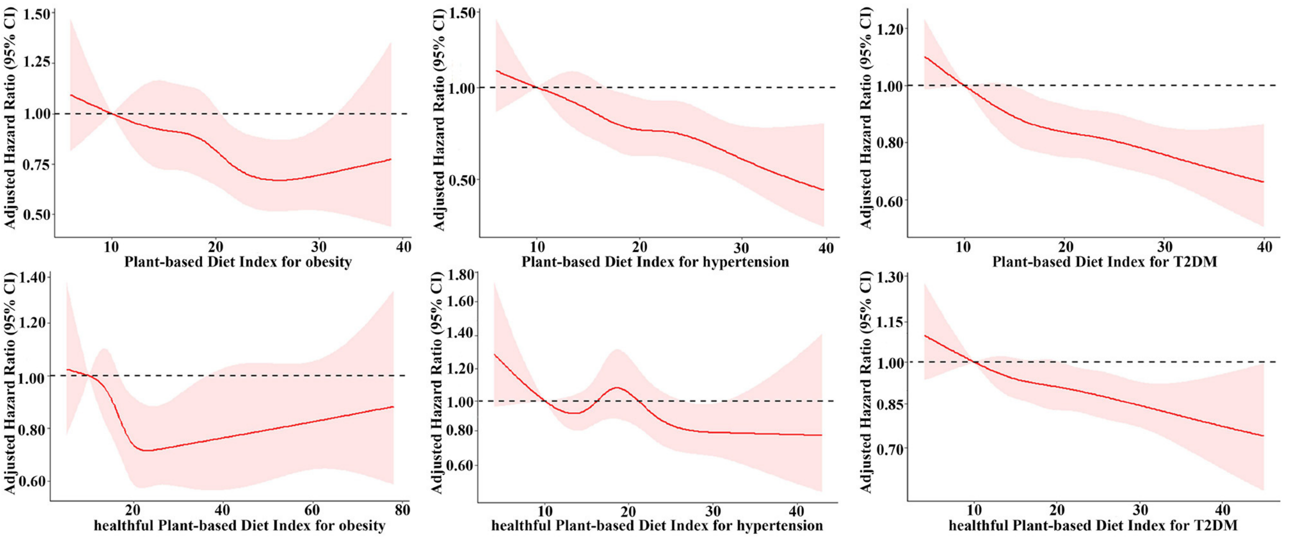

FIGURE 2 | Adjusted hazard ratios and 95% confidence intervals for incident overweight/obesity, hypertension and type 2 diabetes according to the continuous PDI and hPDI. Adjusted for age, urban and rural, sex, total energy intake, education, physical activity, smoking status, alcohol drinking, baseline systolic and diastolic blood pressure, and BMI. BMI, body mass index; T2DM, type 2 diabetes mellitus.

consecutively, there was a statistically significant 7% reduction in the risk of hypertension for every 1 SD increase in the index (HR: 0.93, 95% CI: 0.87–1.00). This association was reflected when we visually described the association between hPDI and the incidence of hypertension (**Figure 2**). The full adjustment hypertension prediction model yielded an AUC of 0.749 (95% CI: 0.730–0.768) for PDI and 0.747 (95% CI: 0.728–0.766) for hPDI, with no significant difference ($p = 0.104$) (**Figure 3B**).

Risk of T2D by Baseline PDI and hPDI Quartiles

During 83,633 person-years of follow-up, we recorded 720 cases of diabetes. In the fully adjusted model, a higher PDI/hPDI was significantly associated with a reduced risk of developing T2D (**Table 2**). A 21% lower risk of developing diabetes was observed in the highest PDI quartile (HR: 0.79, 95% CI: 0.72–0.87, p-trend < 0.001) and a 16% lower risk of developing diabetes was observed in the highest hPDI quartile (HR: 0.84, 95% CI: 0.75–0.93, p-trend $= 0.001$). When PDI/hPDI was assessed consecutively, the risk of developing diabetes decreased by 7% (95% CI: 0.90–0.96) and 6% (95% CI: 0.92–0.98) for each 1 SD increase in the index. The association between PDI/hPDI and the risk of developing diabetes was also shown in the restricted cubic spline, indicating that with increasing PDI/hPDI the risk of developing diabetes showed a significant downward trend (**Figure 2**). The AUC for the full adjustment T2D prediction model was 0.741 (95% CI: 0.715–0.767) for PDI and 0.740 (95% CI: 0.714–0.766) for hPDI, with no significant difference ($p = 0.682$) (**Figure 3C**).

Stratified Analyses

We performed a stratified analysis. In the present study, after fully adjusting for relevant confounding, we found that higher PDI and hPDI scores were significantly and negatively associated with the risk of being overweight/having obesity, hypertension, and T2D in the younger population (age < 55 years) ($p < 0.05$), while the linear trend of increasing PDI/hPDI quartiles with associated diseases in the younger age group remained highly significant (p-trend < 0.02). However, in older people (age ≥ 55 years), there were no statistically significant differences ($p > 0.05$), except for a significant negative association between PDI score and risk of hypertension ($p < 0.05$) (**Table 3**).

In a gender-stratified analysis, after fully adjusting for relevant confounding, we found that higher PDI and hPDI scores showed significant negative correlations with the risk of being overweight/having obesity in women ($p < 0.05$) and with risk of T2D in both men and women ($p < 0.05$), while we found that only the PDI score showed a significant negative association with the risk of hypertension in both sexes ($p < 0.05$) (**Supplementary Table S2**).

DISCUSSION

In this relatively large nationwide cohort study of adults, we found that higher scores on PDIs were associated with a reduced risk of being overweight and having obesity, hypertension, and T2D. Specifically, PDI and hPDI were negatively associated with the risk of having obesity and T2D, and PDI was also negatively associated with the risk of hypertension, and these associations were independent of BMI and other risk factors. Previous prospective studies and meta-analyses have concluded that higher PDI and hPDI scores are negatively associated with lower reductions in weight gain over 4-year intervals (10). Plant-based diets, especially those rich in high-quality plant foods, significantly reduce the risk of T2D (9, 13, 33–35). PDI or hPDI

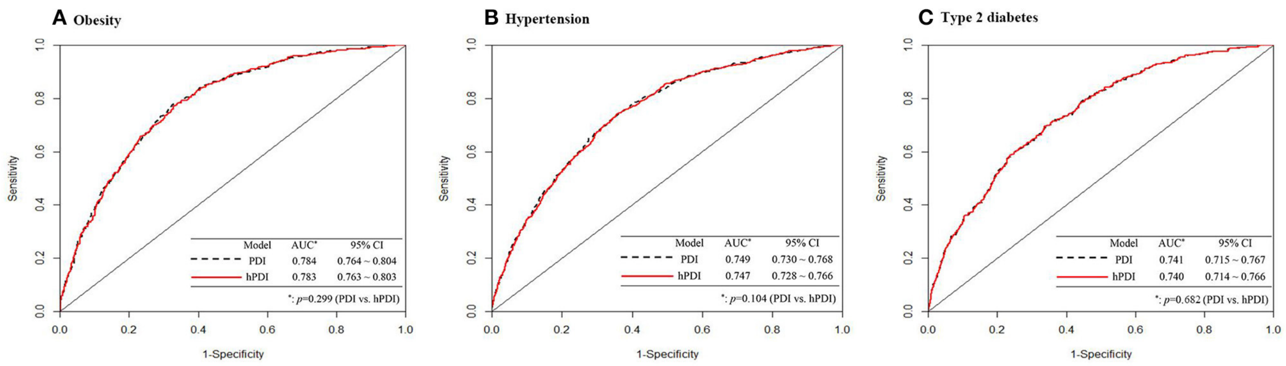

FIGURE 3 | (A–C) Receiver-operating characteristic curves for PDI and hPDI predicting incident overweight/obesity, hypertension and type 2 diabetes. Model_{PDI} and Model_{hPDI}: Adjusted for age, urban and rural, total energy intake, education, physical activity, smoking status, alcohol drinking, baseline systolic and diastolic blood pressure, and BMI. AUC: area under curve.

TABLE 3 | Hazard ratios (95% CI) for overweight/obesity, hypertension and type 2 diabetes according to quintile of the overall & healthful plant-based diet indices, stratified by age.

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	*P*-trend[a]
Overall plant-based diet index						
Overweight/obesity						
<55 years	1.00	0.97 (0.76, 1.24)	0.90 (0.71, 1.16)	0.80 (0.62, 1.04)	0.68 (0.51, 0.90)	<0.001
≥55 years	1.00	0.56 (0.31, 0.99)	0.62 (0.34, 1.10)	0.55 (0.28, 1.08)	0.79 (0.44, 1.41)	0.38
Hypertension						
<55 years	1.00	0.80 (0.63, 1.01)	0.78 (0.63, 0.98)	0.80 (0.62, 1.03)	0.62 (0.49, 0.80)	0.02
≥55 years	1.00	0.87 (0.59, 1.30)	0.82 (0.52, 1.28)	1.10 (0.70, 1.74)	0.58 (0.35, 0.95)	0.08
Type 2 diabetes mellitus						
<55 years	1.00	0.89 (0.80, 1.01)	0.88 (0.80, 0.98)	0.86 (0.77, 0.95)	0.80 (0.72, 0.89)	<0.001
≥55 years	1.00	0.94 (0.75, 1.17)	0.87 (0.68, 1.11)	0.92 (0.72, 1.17)	0.87 (0.67, 1.12)	0.30
Healthful plant-based diet index						
Overweight/obesity						
<55 years	1.00	0.84 (0.65, 1.09)	0.66 (0.51, 0.86)	0.79 (0.62, 1.01)	0.74 (0.58, 0.95)	0.01
≥55 years	1.00	1.31 (0.73, 2.34)	1.23 (0.65, 2.32)	1.00 (0.51, 1.97)	0.97 (0.54, 1.80)	0.78
Hypertension						
<55 years	1.00	0.96 (0.77, 1.20)	0.99 (0.77, 1.27)	0.92 (0.73, 1.16)	0.77 (0.60, 0.98)	0.04
≥55 years	1.00	1.20 (0.80, 1.80)	1.34 (0.86, 2.11)	1.08 (0.64, 1.82)	0.87 (0.59, 1.40)	0.61
Type 2 diabetes mellitus						
<55 years	1.00	0.95 (0.86, 1.05)	0.89 (0.76, 0.99)	0.91 (0.82, 1.01)	0.84 (0.76, 0.94)	0.002
≥55 years	1.00	0.99 (0.81, 1.22)	0.98 (0.77, 1.26)	0.95 (0.74, 1.21)	0.92 (0.72, 1.16)	0.44

Adjusted for age, urban and rural, sex, total energy intake, education, physical activity, smoking status, alcohol drinking, baseline systolic and diastolic blood pressure, and BMI.
[a]*p-Value when we assigned the median value to each quintile and entered this as a continuous variable in the model.*

may moderately improve the risk of hypertension (8, 36). Our findings are generally consistent with the current knowledge that adherence to a higher PDI and hPDI score is associated with a reduced risk of becoming overweight/developing obesity, hypertension, and T2D, regardless of the health effects of specific food types.

However, our results are partially inconsistent with the findings of previous studies. First, although we found that higher PDI and hPDI scores were associated with a lower risk of T2D (HR_{PDI}: 0.79, 95% CI: 0.72–0.87; HR_{hPDI}: 0.84, 95% CI: 0.75–0.93), the association between the hPDI score and the risk of T2D was weaker than that of the PDI. This may be due to different food type compositions. Some studies found no clear association between vegetable and nut intake and diabetes incidence (37), and a much higher intake of vegetables than other healthy plant-based foods were found in our population, which may have somewhat weakened this association. Second, current evidence suggests that high hPDI score significantly reduces the risk of developing hypertension, but the relationship between PDI and the incidence of hypertension has not been established. The US population study concluded that high adherence to both PDI and hPDI significantly reduced the risk of hypertension by 12 to 16% (8). A recent study in a Korean population found that high hPDI score significantly reduced the risk of hypertension by 35% (HR: 0.65, 95% CI: 0.57, 0.75), but PDI was not associated with hypertension (36). Our study contradicted the findings of the Korean population study; it found a significant negative association between high adherence to PDI and hypertension incidence, but no significant association was observed between high adherence to hPDI and hypertension incidence. However, receiver operating characteristic curves show that PDI and hPDI were found to be essentially the same for the AUC of risk of hypertension. Thus, there could be several reasons for this. Firstly, the difference may be influenced by demographic characteristics (socio-demographic characteristics, country, age structure, etc.). The analysis of Korea, which included people aged 40–69 years, and our study, which included people aged ≥18 years, found a significant negative association between high adherence to hPDI and the incidence of hypertension in people aged <55 years (HR_{PDI}: 0.62, 95% CI: 0.49–0.80; HR_{hPDI}: 0.77, 95% CI: 0.60–0.98). Secondly, the inverse U-shaped distribution of whole grain intake and the W-shaped distribution of meat intake observed in the hPDI quintiles may explain the contradictory findings and non-linear associations for hypertension. In addition, differences in food consumption patterns and methods of obtaining dietary data were associated with the contribution of the PDI and hPDI scores. Of course, the number of available studies on PDI and hPDI is limited, and more studies are needed to analyze these associations.

Notably, although PDI and hPDI were negatively associated with the risk of having obesity, the non-linear association showed a U-shaped trend of decreasing and then gradually increasing the risk of overweight/obesity with increasing PDI/hPDI. Marleen A's study showed that refined grain/high glucose index intake are likely to facilitate weight increasing (38). The U-shaped distribution of refined grain intake observed in the hPDI quintiles and the liner distribution of refined grain intake observed in the PDI quintiles may explain the non-linear association for overweight/obesity in Chinese population.

In the age group analysis, adherence to high PDI and hPDI in people ≥55 years were not found to significantly reduce the risk of developing overweight/obesity, T2D, and hypertension, which may be a result of the progressive decrease in caloric needs of older adults and the progressive increase in the need for nutrients not available in plant foods (e.g., unsaturated fatty acids), with some studies showing that a dietary intake of unsaturated long-chain fatty acids has a protective effect (39). In addition, the risk of diabetes and hypertension is higher in the elderly population than in the younger population because of their physical function. Also, this result is consistent with the results of the Nurses' Health Study 2 data from Ambika Satija et al.'s study, but not with the pooled results from that study (9). Some factors, including differences in dietary patterns across populations, the methods used to obtain dietary data, and the calculation methods used to develop these indices, may have determined these differences. In the gender analysis, women adhered to both the high PDI and hPDI in favor of a lower risk of obesity. This may be because female vegetarians have significantly higher adiponectin levels than non-vegetarians, and studies have shown that lipocalin has protective metabolic effects that reduce inflammation and endothelial dysfunction, which in turn reduces the risk of being overweight/having obesity (40, 41).

Overall, higher PDI and hPDI scores are associated with a decreased risk of overweight/obesity and the development of their metabolic diseases. Our analysis of the correlation and concordance between PDI and hPDI showed several common components between these indices, with higher scores on these indices implying higher intakes of fruits, vegetables, whole grains, nuts, and legumes and lower intakes of red and processed meats. PDI and hPDI were associated with a similar degree of reduced risk of developing chronic diseases. In addition, some studies have shown no significant association between the consumption of vegetables, fruits, and nuts in a healthy plant-based diet and the risk of developing T2D (37), which may have somewhat weakened the protective effect of hPDI on chronic disease. Taken together, these findings support the usual dietary recommendations that recommend a higher intake of plant foods (e.g., whole grains, fruits, vegetables, nuts, and legumes) and a lower intake of animal foods (especially red meat and processed meat), which are captured by the PDI and hPDI.

Our results regarding the association between plant-based diets and overweight/obesity, T2D, and hypertension are biologically plausible when considering the macronutrient and micronutrient composition of plant-based dietary patterns. Those adhering to a higher hPDI consumed higher amounts of protein (12.2–14.5% of total energy), fiber, and potassium compared to those in the lowest quartile. Randomized controlled trials have reported that higher dietary protein and fiber intake are associated with lower systolic and diastolic blood pressure (42). Similarly, a higher potassium intake is believed to lower blood pressure through vasodilation and vascular homeostasis (43). In addition, plant-based diets may also reduce obesity and T2D through several mechanisms (44, 45). Such diets are rich in micronutrients, such as dietary fiber, antioxidants, unsaturated fatty acids, and magnesium, and low in saturated fat. Epidemiological and clinical studies have shown that highly viscous and soluble fiber, lower levels of saturated fat, and lower caloric content have beneficial effects on improving long-term glucose metabolism and reducing energy intake (46).

The strength of our study is that the PDIs we used accounted for dietary changes in the consumption of plant-based and animal-based foods in an integrated manner as compared to previous studies that used single nutrients or single food groups alone. We found that high adherence to plant-based diet scores was effective in reducing the risk of common non-communicable diseases (overweight/obesity, diabetes, and hypertension). This is consistent with previous analyses of individual foods and the risk of weight change, diabetes, and hypertension development in these cohorts (4–7). Another major strength of our study is the detailed collection of dietary intake data, which were collected through repeatedly validated 24-h dietary records based on an extensive database containing 6,900 food items. This allowed us to examine in detail the association between different types of food groups and various chronic diseases (8).

Nonetheless, certain limitations should be recognized. First, although our model adjusts for a variety of potential confounders, residual confounding by unavailable diets, certain medical condition variables, or metabolic factors may persist. Second, participants were categorized into quintiles of the plant-based diet score based on the intake distribution. All of these metrics limit inferences about the absolute intake of animal or plant foods associated with a lower risk of obesity, T2D, and hypertension. Finally, due to database limitations, the 9–11-year time frame is relatively short when looking at total life expectancy, and the young adults in this cohort are unlikely to develop diabetes and hypertension in the next 9–11 years but may still have a higher risk of future diabetes and hypertension, so a longer time frame may be needed for future confirmation.

CONCLUSION

The PDI and hPDI scores were very similar in the Chinese population in that they scored positively for fruits, vegetables, whole grains, nuts, and legumes but had the opposite scores for all animal products. Our findings emphasize that adherence to a whole plant-based diet helps reduce the risk of T2D, obesity, and hypertension in Chinese adults, particularly for those <55 years of age. Our findings support a shift toward emphasizing plant-based diets to improve health outcomes. Further understanding of how the quality of plant-based diets is associated with chronic disease will be needed in the future, which will help develop dietary strategies to prevent diabetes, hypertension, and related chronic diseases.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: Our study relied on data from CHNS. The datasets using during the current study are available at https://www.cpc.unc.edu/projects/china.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Review Board of the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Health of the Chinese Center for Disease Control and Prevention approved the investigation (No. 201524). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

BC, JZ, MQ, and SX conceived and designed the study. BC and JZ analyzed the data. BC and MQ wrote the first draft of the manuscript. BC, JZ, MQ, WX, ZZ, XL, and SX contributed to the writing of the manuscript and agreed with the manuscript's results and conclusions. SX helps in funding acquisition. All authors have read and confirm that they meet, ICMJE criteria for authorship.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2022.881901/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Brief Remote Intervention to Manage Food Cravings and Emotions During the COVID-19 Pandemic: A Pilot Study

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As a result of the COVID-19 pandemic people have endured potentially stressful challenges which have influenced behaviors such as eating. This pilot study examined the effectiveness of two brief interventions aimed to help individuals deal with food cravings and associated emotional experiences. Participants were 165 individuals residing in United Kingdom, Finland, Philippines, Spain, Italy, Brazil, North America, South Korea, and China. The study was implemented remotely, thus without any contact with researchers, and involved two groups. Group one participants were requested to use daily diaries for seven consecutive days to assess the frequency of experience of their food cravings, frequency of giving in to cravings, and difficulty resisting cravings, as well as emotional states associated with their cravings. In addition to completing daily food diaries, participants in group two were asked to engage in mindful eating practice and forming implementation intentions. Participants assessed their perceived changes in eating, wellbeing, and health at the beginning and end of the intervention. Repeated measures MANOVAs indicated that participants experienced significantly less food cravings (i.e., craving experience, acting on cravings, difficulty resisting), as well as lower intensities of unpleasant states associated with cravings across time (T1 vs. T7). In contrast to our hypothesis, the main effects of the group (food craving diary vs. food craving diary and mindful eating practice) were not significant. Participants reported less eating and enhanced wellbeing at the end of the study (T7 vs. T1). Our findings can be used to inform future remote interventions to manage food cravings and associated emotions and highlight the need for alternative solutions to increase participant engagement.

Keywords: lockdown, confinement, mindful eating, diary, emotion

INTRODUCTION

On March 11th 2020, the World Health Organization declared COVID-19 a pandemic, and by September 22nd 2021 there have been nearly 230 million cases and over 4.7 million deaths worldwide (World Health Organisation, 2021). Being highly contagious, a common containment measure adopted by many nations during the pandemic was a mandated "lockdown". This resulted in the closure of schools, businesses and places of congregation, and travel restrictions. During this time, people were allowed to leave their homes only to purchase essential items (e.g., food, medicines), seek essential treatment, go to work (only for jobs considered essential), or to assist and care for dependents. Adjusting to life during the COVID-19 pandemic presented considerable challenges such as home-schooling, learning new ways of working, reduced opportunity to pursue hobbies dependent on congregating, and lost time spent with friends and family.

An increase in stress, depression, anxiety, and other unpleasant emotions was reported as a consequence of the COVID-19 pandemic (Salari et al., 2020). Also evidenced has been the experience of anxiety due to poor eating habits with individuals reporting using food to feel better (Di Renzo et al., 2020). Notably, increased calorie consumption derived largely from foods high in fats and sugars, thus leading to weight gain (Shen et al., 2020). Increasing calorie intake via unhealthy food choices when experiencing unpleasant emotions in the absence of internal hunger cues is termed emotional eating (van Strien et al., 2007). However, whilst emotional eating was originally defined as eating in response to unpleasant emotions, a number of studies show that pleasant emotions can also elicit increased food intake (Nicholls et al., 2016; Devonport et al., 2019). Therefore, in the present study we considered both unpleasant and pleasant emotions.

Exposure to stress during the pandemic, and the subsequent potential for unpleasant emotions and associated weight gain, increases risk of adverse outcomes from COVID-19. Results from a survey administered to 1,140 individuals residing in different countries showed an increase in reported eating and weight, especially for those reporting highest decrease in physical activity as a consequence of the COVID-19 pandemic (Ruiz et al., 2021). Targeting eating behavior through provision of remote interventions that could be easily administered and would not require the presence of a practitioner is, therefore, a critical strategy to ameliorate the impact of COVID-19 and is the focus of the proposed research.

Traditional calorie-controlled diets can lead to individuals feeling deprived of food, which can result in food cravings and decreased sensitivity to sensations of hunger and fullness (Meule, 2020). Interventions that take account of the psychological processes underpinning eating behavior may have greater long-term success than nutritional only interventions (Braden et al., 2016). For example, a food craving is an intense desire for specific foods that are difficult to resist, and a leading cause of dieting failure (Meule, 2020). Cravings present a non-hunger cue relevant to the COVID-19 pandemic situation. Eating behavior interventions typically address cravings through the avoidance or removal of cues or situations which are known triggers (Nannt et al., 2019). However, during lockdown, people have been purchasing high quantities of long-life food high in sugar, trans fat, and salt content, which contribute to obesity (Rundle et al., 2020). Such changes in food purchasing make it difficult to address food cravings through cue avoidance, as individuals are living with larger quantities of unhealthy food within their immediate environment.

In selecting interventions for use in the present study, there was a need to be sensitive to considerations of participant need and participant burden. The term "zoom fatigue", which gained momentum during COVID-19, reflects increased personal, professional, and psychological demands resulting from higher use of technology for work and social purposes (Brown et al., 2021). The ongoing pandemic necessitated the use of online means for facilitating remote interventions. Cognisant of a need to account for the possibilities of zoom fatigue and increased demands resulting from home working, schooling, carer responsibilities, etc., we sought to deliver brief interventions previously established as effective in regulating unpleasant emotions and resisting food cravings when delivered remotely. Specifically, in our remote intervention we implemented food craving diaries and mindful eating techniques and recorded the type of food individuals gave into after cravings.

Evidence suggests that maintaining a daily eating diary is associated with significantly more weight loss than an inconsistent recording (Berkowitz et al., 2003). This is because a daily diary increases awareness of eating habits, and when the focus is on emotional antecedents of food cravings, self-monitoring can provide a more complete understanding of eating behaviors. Not only can this help in targeting eating interventions appropriately, but the diary in itself also presents an intervention due to its role in increasing awareness (Jimoh et al., 2018).

Mindful eating is based on the construct of mindfulness, which refers to paying attention on purpose, non-judgmentally, and in the present moment (Kabat-Zinn, 1990). While some scholars consider mindfulness a skill that can be practiced (e.g., Bishop et al., 2004), others consider it a dispositional trait present in every person (Brown and Ryan, 2003). Mindful eating is viewed as a process that involves three aspects: (1) bringing attention to present moment experience, that is, the process of eating, taste, smells, thoughts, and feelings that arise during a meal, as well as internal cues of hunger and fullness; (2) considering one's thoughts and emotions as separate from oneself, also called decentering; and (3), acceptance of one's experiences, also called non-reactivity (Tapper, 2022).

Most common mindful eating practices include present moment awareness of the sensory properties of food, internal bodily sensations or cues that elicit eating or the urge to eat, and decentering from or acceptance of cravings or food-related thoughts (Tapper, 2022). Because awareness of one's emotions is necessary for successful emotion regulation, mindful eating would appear suitable in facilitating the management of emotionally elicited eating. Support for this contention comes from research demonstrating that mindfulness treatment is linked to anatomical changes in areas associated with cortical regulation and emotion regulation (Hölzel et al., 2011). Research also suggests that mindful eating reduces impulsive eating in response to emotional stressors and re-engages intuitive processes of eating regulation (Kristeller and Wolever, 2010). Focusing on sensory experiences (e.g., taste and texture), increases awareness of satiety resulting in reduced consumption of sweet foods (Mason et al., 2016) and lower calorie intake (Arch et al., 2016).

Forming implementation intentions is a self-regulation strategy that involves a volitional process and is thus concerned with filling the gap between intention and behavior by planning the action to achieve a certain goal (Gollwitzer, 1996; Bieleke et al., 2021). Such strategy, which takes the if-then format - "*If* (situation), *then* I will do (behavior)", helps individuals specify when, where, and how to perform goal-directed responses. Research has shown that forming implementation intentions is an effective strategy in the reduction of fat consumption (Vilà et al., 2017) and in modifying emotional outcomes (Webb et al., 2012).

Widespread use of the internet, smartphones, and mobile technology (Roberts et al., 2017) have enabled the rapid growth of brief online health and mental health programmes, including mindful eating training (Mason et al., 2018) and food craving diaries (Schumacher et al., 2018). Implementing interventions online not only circumnavigates the challenges of intervention delivery whilst social distancing measures are in place, but also presents scope for reaching a wider audience (Moller et al., 2017). Previous research shows that remote interventions can reduce unhelpful eating behaviors (Mason et al., 2018; Schumacher et al., 2018). A consideration in delivering remote intervention studies is that participants are truly volunteers. There is no associative incentive for participation, or power differentials influencing participation that are omnipresent in research undertaken by academics using student populations. The implication being that they have given thought to their circumstances, their emotions and eating, and made a commitment to attempt change. Thus, this presents an opportunity to evaluate the acceptability of interventions provided and establish impact.

Study Purpose

The purpose of this pilot study was to explore the effectiveness of a seven-day remote intervention to manage food cravings during the COVID-19 pandemic. The intervention included two conditions, (a) completion of a food craving diary and (b) completion of diary and mindful eating practice. Food craving diaries and emotional states assessments were provided with the intention of helping individuals identify emotional antecedents of food cravings. Mindful eating guidelines were provided to better manage food cravings when they inevitably did occur. Both conditions sought to challenge eating in response to non-hunger cues, specifically emotions, known to be associated with snacking on highly fatty and sugary food (Summerbell et al., 1995). Differences in food cravings, emotional states associated with cravings, changes in eating, perceived wellbeing, and physical and mental health were examined. Based on previous experimental evidence on the effectiveness of mindful eating on energy intake (Tapper, 2022) and implementation intentions (Bieleke et al., 2021), it was hypothesized that a mindful eating practice combined with the completion of a food-craving diary would be more effective in helping individuals manage their food cravings and related emotional experiences than the completion of the food-craving diary alone, which would result in decreased eating and increased perceptions of wellbeing, physical and mental health.

MATERIALS AND METHODS

Participants and Procedures

An a priori sample size calculation for repeated measures MANOVA design with an anticipated medium effect size of 0.30, power level of 0.80, and $P < 0.05$ for two groups and seven measurement times, suggested a minimum sample size of 158 participants (G*Power 3.1.9.6 software; Faul et al., 2007). The recommended sample for the between-subjects main effect (correlation among repeated measures = 0.5) was 52 participants, and for the within-subjects main effect 20 participants. The only criterion for participation in the study was being over 18 years of age.

Up to 3,262 participants started the initial assessments. Of the 2,075 who completed the initial assessments, 171 completed the study (see **Figure 1**). Data screening suggested the removal of six cases identified as outliers using the Mahalanobis' distance criterion. The final sample consisted of 165 participants including women ($n = 132$), men ($n = 32$), and one person who identified as other gender. Participants were aged 18 to 72 years ($M = 33.64$, $SD = 12.42$) and resided in different countries (i.e., UK 24%, Finland 23%, Philippines 22%, Spain 12%, Italy 8%, Brazil or Portugal 4%, North America 4%, South Korea 2%, and China 1%).

The study was conducted between May and November 2020, completely online; thus, there was no contact between participants and researchers. The study was implemented using Qualtrics. Links to the study were distributed via social media (e.g., Twitter, Facebook, LinkedIn), and other public channels (e.g., Universities). Participants were presented details about the purpose and protocol, and assurances of anonymity and confidentiality, after which they provided informed consent, which was granted electronically. Participation was voluntary and no compensation for taking part in the study was given. Participants could exercise their right to withdraw from the study by exiting the browsing window. Ethics approval was granted by the University of Wolverhampton (01/20/AF1/UOW).

Separate Qualtrics projects were developed to include information in the respective languages of the participants. Instructions, measures, and guidelines were translated from English into other languages (i.e., Finnish, Filipino, Spanish, Italian, Portuguese, Korean, and Chinese) using back translation procedures (Brislin, 1986). This comprised (a) translation into the respective languages by bilingual individuals with efforts made to include most common or used language, (b) back-translation into English, (c) comparison of translated and original versions by experts with the focus on maintaining the meaning of the original texts.

This randomized pilot study was a pre-test post-test research design, including two conditions, and seven consecutive

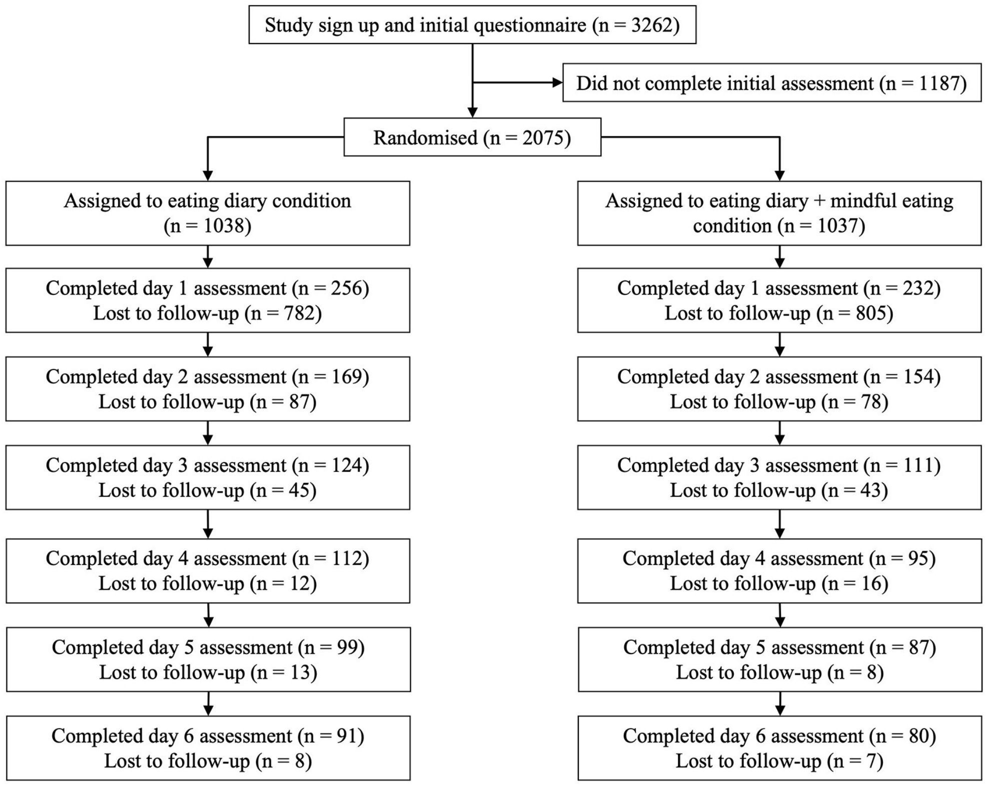

FIGURE 1 | Flow diagram representing participants' attrition from the survey and follow-up assessments.

assessments (T1 through T7) divided in three phases: (1) initial assessment, (2) follow up assessments, and (3) evaluation.

Measures

Phase 1: Initial Assessment

Participants provided demographic information such as age, gender, country of residence, and ethnicity. In addition, they completed the following measures at the beginning and at the end of the study.

Perceived Changes in Eating and Wellbeing

Two single items were used to assess participants' changes in their eating and wellbeing respectively, as consequence of the COVID-19 pandemic. Participants were asked to rate changes in eating by answering to the stem question "I feel that I currently eat…" on a 11-point scale ranging from −5 (*less*) to +5 (*more*), with 0 indicating *no change.* Participants assessed their perceptions of wellbeing by responding to the question "I feel that my wellbeing is…" on an 11-point scale ranging from −5 (*significantly decreased*) to +5 (*significantly increased*), with 0 indicating *not changed*. These two items were developed for another study that explored changes in working situation, health routines, and wellbeing in a larger sample (Ruiz et al., 2021). Single items were used as a viable alternative to reduce burden and increase willingness to complete the measures (Allen et al., 2022).

Physical and Mental Health

Two items from the SF-8 Health Survey (Ware et al., 2001) measured participants' physical and mental health. Specifically, physical health was measured by the following item "Overall, how would you rate your health during the past week?" which was rated on a six-point scale ranging from 1 (*very poor*) to 6 (*excellent*). As an indicator of mental health, using the same timeframe of "during the past week", a second item asked participants to assess "How much did personal or emotional problems keep you from doing your usual work, school or other daily activities?" The following anchors were used: 1 (*not at all*), 2 (*very little*), 3 (*somewhat*), 4 (*quite a lot*), and 5 (*could not do daily activities*).

Food Craving Diary

A food craving diary was developed including three questions. The first question assessed the frequency of food cravings experienced (i.e., "How often have you experienced a food craving today?") and was rated using the following anchors: 0 (*never*), 1 (*rarely*), 2 (*sometimes*), 3 (*often*), 4 (*always*). The second question measured the frequency of participants giving in to cravings (i.e., "How often did you give in to cravings and eat the food today?") and was rated using the following anchors: 0 (*never*), 1 (*rarely*), 2 (*sometimes*), 3 (*often*), 4 (*almost every time*). The third question assessed participants' difficulty resisting the craving (i.e., "How difficult was it to resist temptation?") which was rated on the following anchors: 0 (*easy*), 1 (*a bit difficult*), 2 (*difficult*), 3 (*very difficult*), 4 (*so difficult that I gave in*). In addition, participants were asked to indicate whether the most common type of food ingested following cravings were sweet foods (e.g., cake, biscuits, confectionary, sweets) or savory foods (e.g., crisps, popcorn, pretzels, meat snacks). In the current study, acceptable reliability was found for the three first questions for participants who completed the first assessment ($n = 2075$) with a Cronbach alpha value (α) of 0.789, and McDonalds' omega (ω) value of 0.792.

Emotional States Associated With Food Cravings

Participants were requested to rate the intensity of nine emotional states (i.e., energetic, angry, anxious, happy, relaxed, miserable, tired, bored, and frustrated) to indicate their experiences at the time of the strongest food craving. These emotions represent the hedonic valence (pleasure-displeasure) and activation (high-low) described in Russell (1980) circumplex model of affective experiences. The intensity of these emotional states was rated on a 6-point Likert scale: 0 (*none at all*), 1 (*a little*), 2 (*moderately*), 3 (*quite a bit*), 4 (*a lot*), 5 (*a great deal*). If the emotion they experienced at the time of the strongest craving was not included in the list, they could indicate their own.

Phase 2: Follow up Assessments

After participants indicated their gender (male, female, other), they were randomly assigned to either food craving diary (FCD) group ($n = 88$) or food craving diary and mindful eating (FCDM) group ($n = 77$) within their chosen gender category (see **Figure 1**). This was done for each participating country.

FCD group participants completed the food craving diary and assessed their emotional states associated with food cravings for six consecutive days. In addition to doing this, FCDM group participants were provided guidelines (see Section Mindful Guidelines Before Eating and and Mindful Guidelines During Eating) to follow before and during eating for mindful eating practice. Participants were requested to provide their email address to receive daily project reminders and a link to follow-up surveys for the duration of the study. To ensure anonymity, automatic reminders were created within the Qualtrics platform and were sent out at the end of the following day. Follow-up surveys were sent at around 8 pm and included the food diary for FCD group, and food diary and mindful eating guidelines for FCDM group. Mindful eating guidelines, which participants were encouraged to follow every day, were available to download each day.

Mindful Guidelines Before Eating

One aspect of mindful eating is to recognize and accept the ebb and flow of different emotions that might lead to emotional eating. Having completed the food craving diary, think about the connections between your emotions and a desire to eat. For example, did you experience food cravings when feeling lonely, sad, angry, disappointed, excited, anxious, bored, or guilty/ashamed? It might help you to understand emotional triggers for eating if you think about how you want to feel during/after eating. For example: If you want to feel more energized, this might indicate the trigger is tiredness; if you want to feel soothed/calm/relaxed, this might indicate the trigger is some kind of anxiety or anger; if you want to feel distracted, this might indicate the trigger is frustration, disappointment, loneliness, anger, or anxiety; if you want to feel entertained, this might indicate the trigger is boredom or loneliness. Sometimes understanding why you have experienced a food craving is enough to resist the craving. Sometimes understanding why you have experienced a food craving gives you the information you need to pick a different coping response that's a better match to the problem you're trying to solve. Think of different ways that you can manage emotions other than eating. For example, you are bored so call a friend. For common triggers for emotional eating, develop a plan that says… when I feel X, doing A, B, C, or D is likely to help. For example, if I feel anxious, then I can listen to music, watch a favorite film, speak with a close friend...

Mindful Guidelines During Eating

The development of mindful eating involves bringing full attention to the process of eating, to taste, smells, thoughts, and feelings that arise during a meal, as well as internal cues of hunger and fullness. To practice mindful eating: (a) focus on noticing food and your body's response to eating; (b) slow down when you are eating; and (c) take time to savor and enjoy your food and notice textures and flavors.

Phase 3: Evaluation

Participants were asked to assess their perceived changes in eating and wellbeing and their physical and mental health. In addition, they assessed perceived easiness and effectiveness.

Perceived Easiness

Participants were asked to rate the ease of completing the food craving diary. In addition, FCDM participants were also asked to rate the ease of undertaking mindful eating practice. Easiness was rated on a 7-point scale ranging from −3 (*I found it hard to do*) to +3 (*I found it very easy to do*), or 0 (*I did not do it*).

Perceived Effectiveness

Participants were requested to assess the effectiveness of the food craving diary, and for FCDM participants also the mindful eating practice in helping them to manage food cravings. Effectiveness was rated on a 7-point scale ranging from −3 (*not at all effective*) to +3 (*very effective*), or 0 (*hard to say*).

Statistical Analysis

Prior to conducting the main analysis, potential differences in mean scores in the study variables at Time 1 (T1) across groups (FCD vs. FCDM) were examined through multivariate analysis of variance (MANOVA). The main analysis comprised four repeated measures MANOVAs to examine: (1) differences in food cravings, (2) emotional states associated with cravings, (3) perceived changes in eating and wellbeing, and physical and mental health, and (4) easiness to follow intervention and intervention effectiveness. The first repeated measures MANOVA examined differences in food cravings data with Time (T1, T2, T3, T4, T5, T6, T7) as a within-subjects factor and Group (FCD, FCDM) as a between-subjects factor, and experience of food cravings, frequency in eating after cravings, and difficulty resisting cravings as outcome variables. A second repeated measures MANOVA was conducted to examine differences in the emotional states (i.e., energetic, angry, anxious, happy, relaxed, miserable, tired, bored, and frustrated) experienced at the time of strongest cravings. Emotional states were included in the analysis separately. A third repeated measures MANOVA was performed to examine differences in perceived changes in eating and wellbeing, and physical and mental health across intervention (T1 vs. T7) and groups. A fourth repeated measures MANOVA was conducted to examine the differences in perceived easiness as well as effectiveness of the food diary across groups.

RESULTS

Preliminary Analysis

Regarding potential differences in mean scores in the study variables at Time 1, MANOVA demonstrated equivalence between groups indicating no significant differences across groups for food cravings experienced, frequency of giving in to cravings, difficulty resisting cravings, or any of the emotional states experienced at T1 Wilk's $\lambda = 0.926$, $F_{(12,152)} = 1.014$, $P = 0.439$, $\eta^2_p = 0.074$.

Adequate reliability for food cravings experience, frequency of giving in to cravings, and difficulty resisting cravings from T1 through T7 was found with $\alpha > 0.799$ and $\omega > 0.813$. The most common types of food consumed after giving into cravings were sweet foods (e.g., cake, biscuits, confectionary, sweets) prior to the intervention (71% of participants) and at the end of the intervention (64%).

There were significant differences in the completion rate for gender (women, men) by group (food craving diary, food craving diary + mindful eating) across the seven days, $\chi^2_{(1,2048)} = 12.55$, $P < 0.001$, with men withdrawing from the study at higher rates than women for both groups (see also **Figure 1**).

Food Cravings and Emotional States

Descriptive statistics for food cravings and emotional states by experimental groups (FCD vs. FCDM) are presented in **Table 1** (Pearson product-moment correlation coefficients at T1 are presented in **Supplementary Table S1**).

Regarding differences in food cravings, as expected, repeated measures MANOVA yielded significant main effects of Time, Wilk's $\lambda = 0.465$, $F_{(18,146)} = 9.334$, $P < 0.001$, $\eta^2_p = 0.535$ for food cravings (i.e., cravings experienced, giving in to cravings, and difficulty resisting the cravings). Contrary to our hypothesis, the effect of Group was not significant, Wilk's $\lambda = 0.993$, $F_{(3,161)} = 0.376$, $P = 0.770$, $\eta^2_p = 0.007$. The effect of Time by Group interaction was also not significant. Ratings of the three craving aspects for each group across the seven days are depicted in **Figure 2**. *Post hoc* analysis on the main effects of Time revealed significantly lower values at the end of the intervention in the frequency of cravings experienced, $F_{(1,163)} = 46.268$, $P < 0.001$, $\eta^2_p = 0.221$, in giving in to cravings, $F_{(1,163)} = 38.975$, $P < 0.001$, $\eta^2_p = 0.193$, and in the difficulty in resisting the cravings, $F_{(1,163)} = 10.174$, $P = 0.002$, $\eta^2_p = 0.059$ (see **Supplementary Table S2** for pairwise comparisons).

In regards to the emotions experienced at the time of the highest food cravings, a repeated measures MANOVA yielded significant main effects of Time, Wilk's $\lambda = 0.374$, $F_{(54,110)} = 3.404$, $P < 0.001$, $\eta^2_p = 0.626$. No significant differences were observed for Group main effect, Wilk's $\lambda = 0.978$, $F_{(9,155)} = 3.384$, $P = 0.941$, $\eta^2_p = 0.022$, and Time by Group interaction, Wilk's $\lambda = 0.622$, $F_{(54,110)} = 1.240$, $P = 0.171$, $\eta^2_p = 0.378$. Reported emotional states intensities for each group are presented in **Figure 3**. *Post hoc* analysis on the main effects of Time indicated that individuals reported significantly lower intensities for all unpleasant states (i.e., angry, anxious, miserable, tired, bored, frustrated) across time. Differences in the intensities of pleasant states reported across the intervention were not significant (see **Supplementary Table S3** for significant pairwise comparisons).

Perceived Changes in Eating and Wellbeing, Physical and Mental Health

Descriptive statistics for perceived changes in eating, wellbeing, physical health, and emotional health reported pre-intervention (T1) and post-intervention (T7) are presented in **Table 2**. MANOVA yielded significant main effects of the Intervention (pre-, post), Wilk's $\lambda = 0.603$, $F_{(4,155)} = 25.530$, $P < 0.001$, $\eta^2_p = 0.397$. The main effects of Group, Wilk's $\lambda = 0.994$, $F_{(4,155)} = 0.226$, $P = 0.923$, $\eta^2_p = 0.006$ or the Intervention by Group interaction, Wilk's $\lambda = 0.972$, $F_{(4,155)} = 1.129$, $P = 0.345$, $\eta^2_p = 0.028$ were not significant. *Post hoc* analysis indicated that participants reported eating significantly less, $F_{(1,158)} = 76.428$, $P < 0.001$, $\eta^2_p = 0.326$), and perceived enhanced wellbeing, $F_{(1,158)} = 57.239$, $P < 0.001$, $\eta^2_p = 0.266$ at the end of the study.

Perceived Easiness and Effectiveness

Regarding the food craving diary, perceptions of easiness in completing it were positive for participants in both FCD ($M = 1.87$, $SD = 1.35$), and FCDM ($M = 1.62$, $SD = 1.61$) groups. Participants' perceptions of its effectiveness in helping them manage food cravings ranged from −3 to +3 ($M = -0.22$, $SD = 1.58$) for FCD group participants, and from −3 to +3 ($M = 0.18$, $SD = 1.34$) for FCDM group participants. MANOVAs did not yield significant main effects of Group in easiness and effectiveness of the food craving diary, Wilk's $\lambda = 0.969$, $F_{(2,158)} = 2.555$, $P = 0.081$, $\eta^2_p = 0.505$. Regarding mindful eating practice, FCDM group participants' perceptions of easiness in carrying it out ranged from −3 to +3 ($M = 0.89$, $SD = 1.62$). FCDM participants felt diary completion to be easier compared to the practice of mindful eating, $t(73) = 3.595$, $P < 0.001$. Moreover, mindful eating practice was perceived as more effective than diary completion, $t(73) = -2.945$, $P = 0.004$.

Participant Feedback

Participants, who provided comments at the end of the study, indicated that they perceived completion of the food craving diary to be an easy task, as the following comment exemplifies:

> *The diary was very easy to complete- bit wary as it is an area that I have work to do however I am also conscious that it could produce*

TABLE 1 | Descriptive statistics of food cravings and emotions for participants in FCD group ($n = 88$) and FCDM group ($n = 77$).

	T1 M (SD)	T2 M (SD)	T3 M (SD)	T4 M (SD)	T5 M (SD)	T6 M (SD)	T7 M (SD)
FCD group							
Food cravings							
Craving frequency	3.2 (0.9)	2.5 (0.9)	2.5 (1.0)	2.4 (1.0)	2.5 (1.1)	2.4 (1.0)	2.5 (1.0)
Give into craving	3.1 (1.1)	2.4 (1.1)	2.6 (1.2)	2.4 (1.2)	2.3 (1.4)	2.4 (1.3)	2.3 (1.3)
Difficulty resisting	2.7 (1.2)	2.1 (1.2)	2.3 (1.4)	2.2 (1.3)	2.2 (1.3)	2.3 (1.3)	2.2 (1.3)
Emotional states							
Energetic	1.1 (1.3)	1.2 (1.3)	1.0 (1.2)	1.1 (1.4)	1.0 (1.3)	1.0 (1.3)	1.2 (1.3)
Angry	0.7 (1.0)	0.4 (0.8)	0.5 (1.0)	0.4 (1.0)	0.3 (0.7)	0.4 (0.8)	0.5 (0.9)
Anxious	1.3 (1.6)	1.1 (1.4)	0.8 (1.4)	0.8 (1.3)	0.9 (1.5)	0.9 (1.4)	0.9 (1.4)
Happy	1.3 (1.4)	1.4 (1.4)	1.3 (1.2)	1.5 (1.5)	1.3 (1.3)	1.2 (1.4)	1.2 (1.3)
Relaxed	1.2 (1.3)	1.4 (1.3)	1.3 (1.3)	1.4 (1.3)	1.1 (1.2)	1.2 (1.3)	1.1 (1.3)
Miserable	1.1 (1.5)	0.7 (1.3)	0.7 (1.2)	0.6 (1.2)	0.8 (1.4)	0.7 (1.3)	0.7 (1.2)
Tired	1.7 (1.7)	1.5 (1.6)	1.6 (1.6)	1.5 (1.6)	1.6 (1.7)	1.5 (1.6)	1.5 (1.6)
Bored	1.9 (1.7)	1.5 (1.6)	1.3 (1.6)	1.2 (1.6)	1.0 (1.4)	1.0 (1.4)	0.9 (1.3)
Frustrated	1.3 (1.6)	0.9 (1.4)	1.0 (1.5)	0.7 (1.3)	0.8 (1.3)	0.7 (1.3)	0.9 (1.4)
FCDM group							
Food cravings							
Craving frequency	3.2 (1.0)	2.8 (1.0)	2.6 (1.1)	2.3 (0.9)	2.2 (0.9)	2.4 (1.0)	2.3 (1.0)
Give into craving	3.0 (1.1)	2.7 (1.2)	2.3 (1.3)	2.2 (1.2)	2.2 (1.2)	2.3 (1.2)	2.2 (1.2)
Difficulty resisting	2.6 (1.1)	2.4 (1.2)	2.1 (1.3)	2.0 (1.2)	2.1 (1.2)	2.2 (1.2)	2.1 (1.3)
Emotional states							
Energetic	1.1 (1.3)	0.9 (1.1)	0.9 (1.2)	1.2 (1.2)	0.9 (1.1)	1.0 (1.2)	0.9 (1.1)
Relaxed	1.6 (1.4)	1.2 (1.3)	1.4 (1.6)	1.2 (1.3)	1.2 (1.2)	1.3 (1.3)	1.1 (1.2)
Happy	1.2 (1.3)	1.1 (1.4)	1.4 (1.3)	1.2 (1.4)	1.1 (1.2)	1.3 (1.3)	1.1 (1.4)
Anxious	1.5 (1.7)	1.3 (1.5)	0.9 (1.2)	0.7 (1.1)	0.8 (1.2)	0.7 (1.1)	0.9 (1.3)
Angry	0.7 (1.1)	0.7 (1.1)	0.5 (1.0)	0.4 (0.7)	0.4 (1.0)	0.4 (0.8)	0.4 (0.8)
Frustrated	1.4 (1.6)	1.3 (1.6)	1.0 (1.5)	0.7 (1.2)	0.6 (1.1)	0.6 (1.0)	0.7 (1.2)
Miserable	1.2 (1.3)	1.0 (1.4)	0.7 (1.2)	0.5 (1.0)	0.6 (1.2)	0.5 (1.0)	0.6 (1.1)
Tired	2.0 (1.6)	1.9 (1.4)	1.4 (1.6)	1.4 (1.5)	1.3 (1.4)	1.3 (1.4)	1.2 (1.4)
Bored	2.2 (1.6)	1.3 (1.6)	1.3 (1.6)	1.1 (1.4)	1.1 (1.4)	1.0 (1.4)	0.9 (1.3)

> *very difficult emotions and which is why I have avoided it. This was a gentle and non-invasive way to start looking at these issues-bringing attention to them without judgement or action plan etc.*

They also noted how the food craving diary helped raise their awareness of emotionally elicited eating prompting them to initiate strategies for healthier eating, illustrated as follows: "*It allowed me to identify negative eating behaviors. I now have fruit at hand always so I eat that instead of finding chocolate if I'm hungry or stressed or bored. So feel like it actually helped*", "*During lockdown we have managed the stress with food and the study has been good to help control the cravings*", and:

> *I had already decided to log my food intake and this study made me think more about when I want to snack and why. Boredom and relaxation really impact my food intake. Keeping busy helps me manage my food consumption. Thank you for helping me with this insight.*

Some participants reported the mindful eating practice to be "*very easy to follow and understand*" and "*not very time-consuming*". However, feedback also described a need to feel confident in using the strategy: *"Becoming aware of the emotions experienced every time we have a craving and how to manage the feelings in those situations is easier than actually doing it"* and:

> *Personally, I think this study has helped me to see the link between emotions and the "need" of snacking. To become aware of this link is a very good first step, however, I have found the mindfulness input very low, especially if someone is not familiar with this concept.*

Mindful eating practice was perceived by some to be a strategy they could, and indeed would like to continue to implement after the completion of the study "*…it helped me to eat more consciously, with more attention. I will continue practicing mindful eating.*" Indeed, several participants expressed a desire to continue using the interventions provided:

Interesting study that drew attention to the influence of one's own emotions. It felt like the week was just getting started - I would like to continue filling out the diary for a longer period of time, or to take part in a longer study.

This was brilliant!! Having 'let myself go' during the lockdown it was just what I needed to kick start healthy eating again. I have lost a total of 5lb this week, and have downloaded an app to track my eating habits to continue progress.

DISCUSSION

This was a randomized pilot study with two conditions (i.e., completion of a food craving diary and completion of food craving diary and mindful eating practice) that examined the feasibility of implementing a remote intervention aimed to manage food cravings and associated emotional experiences during the COVID-19 pandemic. This 7 days remote study was implemented fully online with no contact between participants and researchers. Although limited by the lack of a control group, the study results indicated significant changes in some of the targeted variables. Contrary to our hypothesis, no significant differences were observed due to following mindful eating practice guidelines in addition to completion of a food craving diary.

Descriptive data indicate that tired and bored were the two most intensely experienced unpleasant emotions for participants in both groups at T1. In seeking to explain this finding, it is widely reported that containment measures applied during the pandemic reduced the number of accessible daily activities and enforced changed routines. For example, congregating or mixing with others was no longer permissible, clubs and organized face-to-face activities ceased. As a result, research suggests that time was perceived as slowing down for many when containment measures were in effect, and this conscious experience of time increased feelings of boredom and sadness (Droit-Volet et al., 2020).

Whilst there were no significant between group differences in emotions, there was a significant reduction in the intensity of all unpleasant emotions experienced associated with cravings from T1 to T7 (**Figure 3**). This suggests that the act of completing a daily diary to identify emotional states associated with food cravings may have increased participants' awareness of felt emotions, thereby triggering emotion regulation. When experiencing unpleasant emotions, individuals typically engage in hedonic emotion regulation, characterized by trying to increase the intensity of pleasant emotions and reduce the intensity of unpleasant emotions, unless they believe unpleasant emotions are useful, thereby accommodating utilitarian considerations in emotion regulation (Tamir et al., 2007). The present study suggests that regulation efforts among participants were driven by hedonic motives toward reducing the intensity of unpleasant emotions.

Whilst there was no overall difference between groups in terms of food craving reduction, it is informative to examine patterns in the data, as the reported craving outcomes follow a different pattern over time for each group. Observing these patterns may be helpful in hypothesizing about the function of a combined diary and mindful eating intervention in bringing about behavioral change over time. Observing FCD group participants who received the food craving diary only, there is a significant reduction in the frequency of cravings, giving in to cravings and difficulty in resisting cravings at T2. By contrast, FCDM group participants who received the food craving diary plus mindful eating intervention evidenced a steadier reduction over time. Participants reported greater ease in using the craving diary as compared to the mindful eating intervention. Most participants providing feedback on their experiences with diary completion noted how it increased their awareness of emotions that elicit cravings. Many participants

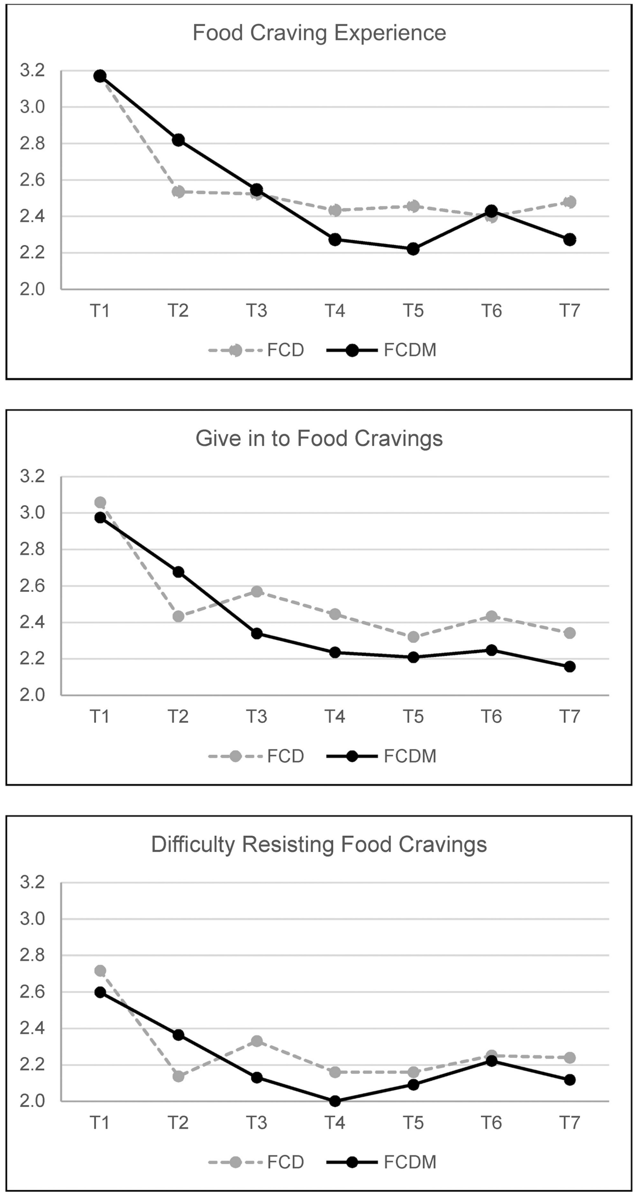

FIGURE 2 | Food cravings across a 7-day intervention (FCD, $n = 88$; FCDM, $n = 77$).

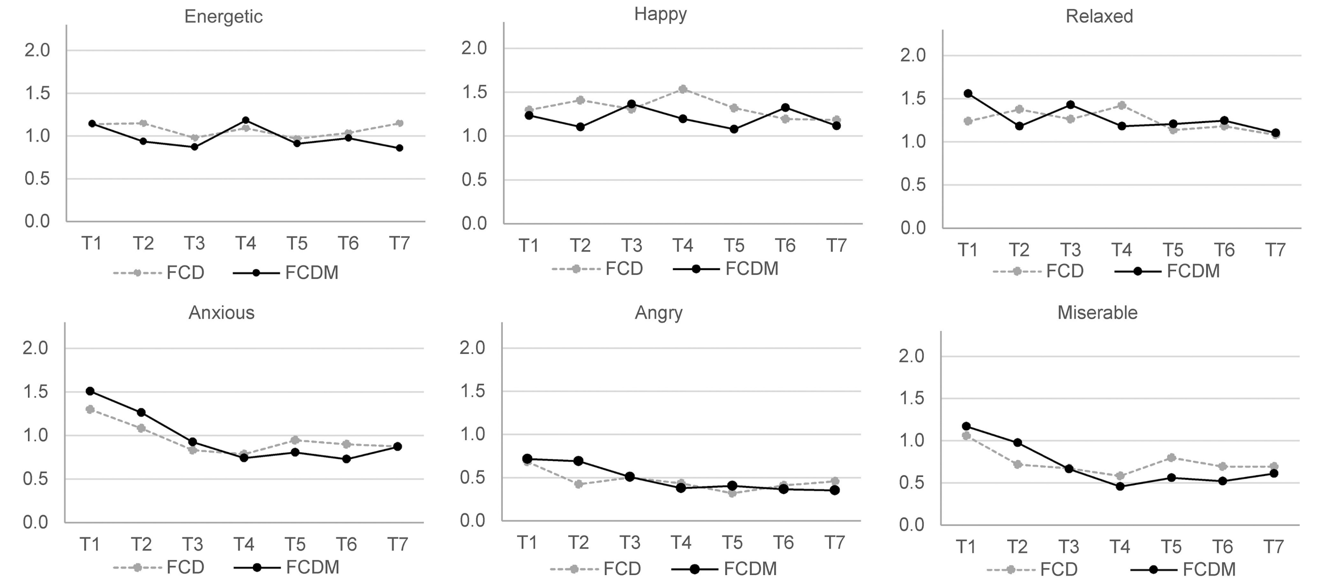

FIGURE 3 | Intensity of emotional states associated with strongest food cravings across a 7-day intervention (FCD, $n = 88$; FCDM, $n = 77$).

then detailed strategies they used to help manage this. FCD group participants, having no guidance on strategies to manage emotionally elicited cravings, likely self-selected strategies they felt confident in utilizing. As such, they did not have the need to learn a researcher prescribed and potentially novel strategy.

FCDM group participants were asked to use mindful eating as a strategy to help manage emotional eating. Whilst we did not evaluate previous experience with mindful eating, we can speculate that for many participants this presented a novel intervention. This novelty might explain the difficulties in complying with this practice, which was reported by some participants and may also account for differences at T2. T2 data suggests that participants in the craving diary only condition showed greater reductions in cravings, acting on cravings, and difficulties in resisting cravings. They also experienced greater reductions in unpleasant emotion. People often struggle to adhere to psychological skills training programmes (Shambrook and Bull, 1999); notably where they find the intervention difficult to follow. This alludes to the possibility that the intervention process is effortful and so might not lead to immediate benefits. Furthermore, where an intervention is perceived as more difficult to follow, an individual may perceive effort invested as producing insufficient benefits. This highlights the importance of setting expectations for intervention use, and setting realistic outcome expectancies, in particular during the early stages of the intervention. It also suggests that for mindful eating, guided practice by an experienced trainer may be necessary to initiate and facilitate practice, rather than the exclusive use of remote online means of intervention delivery and support. Irrespective of intervention condition, unpleasant emotions were stronger triggers for cravings at the beginning but decreased over the week. Happiness as a trigger for food cravings remained the same.

TABLE 2 | Reported changes in eating, wellbeing, physical and emotional health at T1 and T7 for FCD and FCDM group participants.

Variable	Group	T1 *M (SD)*	T7 *M (SD)*
Eating (-5, +5)	FCD	1.06 (2.1)	−0.2 (1.2)
	FCDM	1.49 (1.7)	−0.4 (1.4)
Wellbeing (−5, +5)	FCD	−0.64 (2.2)	0.7 (1.1)
	FCDM	−0.71 (2.0)	0.7 (1.2)
Physical health (1–6)	FCD	3.80 (1.1)	3.7 (0.9)
	FCDM	3.79 (1.1)	3.9 (1.1)
Emotional health (1–5)	FCD	2.47 (1.2)	2.5 (1.1)
	FCDM	2.55 (1.1)	2.5 (1.0)

A final point of discussion relates to participant attrition. A high dropout rate (76%) was observed from the initial assessment ($n = 2075$) to the first follow-up food craving diary ($n = 488$). The rate of attrition decreased across the latter stages of the intervention (see **Figure 1**). Analysis also indicate that recruitment of male participants was lower, and attrition higher. This is in line with previous research undertaken on emotional eating where significant differences in the recruitment and retention of male and female participants have been reported. A systematic review of 14 studies on mindfulness-based interventions for emotional eating (Katterman et al., 2014) included 5 studies who recruited exclusively female samples, and of the 9 remaining, males only represented between 10–37% of the total sample. A similar pattern is observed in studies of related concepts such as weight management. For example, a systematic review of 244 randomized controlled trials of weight loss programmes ($n = 95{,}207$) found that only 27% of participants were men (Pagoto et al., 2012). Research indicates that men perceive weight loss services to be feminized spaces, in which they feel self-conscious and out of place (Elliott et al., 2020). When the contexts of weight and emotion combine, as with emotional eating, then perceptions of this as a "feminized space" may intensify. Emotion is a term that has long been associated with the personal and the feminine (Åhäll, 2018). Thus, interventions based around these concepts may be met with resistance from men due to mismatch with ideologies of masculinity (Isacco, 2015).

Previous research has evidenced high rates of study attrition when delivering remote online interventions (Christensen et al., 2009). Existing explanations for high attrition with remote interventions include a need to provide brief support that supplements remote self-help (Richards and Richardson, 2012) and the ease of access to online interventions which invite browsing and curiosity (Mason et al., 2018). There is qualitative evidence to suggest that some participants found the mindful eating intervention to be the more challenging of the two interventions and would have appreciated additional guidance for its use. As such, for these individuals, perceived difficulty of use may have contributed to a decision to cease participation. However, we propose two further plausible explanations. The first explanation is informed by data from the present study. **Figures 2**, **3** respectively show the greatest decrease in food cravings (experiencing, giving in to, and difficulty resisting), and unpleasant emotions (anxious, angry, miserable, tired, and frustrated) from T1 to T2. At this point, participants had experienced the craving diary or craving diary plus mindful eating intervention. Qualitative data indicate that most participants found the interventions easy to follow, and experienced early benefit, in particular for the food craving diary. It is plausible that facilitated by the remote nature of the research, some participants felt under no obligation to continue with the research once they fulfilled their goals for participation. In other words, where participants perceived they had adequately (by their own self-referenced standards) recognized and regulated unpleasant emotion and associated unwanted food cravings, some may have perceived no further incentive for ongoing participation. The second explanation is informed by the context of the present study, in particular, experiences of "zoom fatigue" commonly reported during COVID-19. It is likely that for some participants, a requirement for daily online diary and survey completion was de-incentivising due to high levels of online fatigue, with priorities for screen time allocated to work and social activities. Likely a combination of all the aforementioned explanations contributed to participant attrition, and consideration should be given to each in designing remote interventions and recruiting participants. For example, by incorporating measures associated with adherence (e.g., motivation for change), establishing means to differentiate curious browsers from those with true interest in the study, and keeping screen time brief and informative. It is worth noting that in the present study participant attrition from day 3 assessment onwards reduced dramatically (**Figure 1**). This suggests that following initial curiosity, where participants were able to establish congruence with their own goals for involvement this was sufficient to ensure ongoing adherence. Indeed, some participants reported that they intended to continue with the interventions provided after the cessation of participatory requirements.

Limitations and Future Research Directions

One aim of this study was to provide participants with brief and easy strategies to regulate their emotions and associated food cravings, which seemed to be appropriate considering the reported changes in eating behaviors during the COVID-19 pandemic (Ruiz et al., 2021). There are several advantages related to the remote format of delivery, which allowed access to geographically dispersed participants with different backgrounds and ages. In this study, the use of technology also facilitated sending daily reminders to participants. However, one of the limitations of daily retrospective assessments is recall bias, where participants may recall more intense experiences rather than those that endure for longer time (Gunthert and Wenze, 2012). Future interventions could use ecological momentary assessment (EMA) (Shiffman, 2009) in which participants are sent repeated cues for self-reporting across the day. This is one of the most advanced methods of recording self-monitoring, and has been advocated for in a systematic review on emotional eating in normal and overweight individuals (Devonport et al., 2019).

The lack of significant differences in food cravings between the two groups may be explained by the individuals' prior experiences of and current engagement in mindfulness practice or with mindful eating practice outside of the study, which was not captured, and thus equivalence across groups cannot be assumed. We recommend that future research captures prior mindfulness training or practice and experience with mindful eating to account for this potential confounding factor.

A further limitation of the present study is that we did not ask participants to report on their perceived need to manage emotionally elicited cravings, or their compliance with the mindful eating guidelines. The extent to which people engaged with the guidelines provided would likely vary and may largely depend on their previous experience. Whilst we did not complete a manipulation check, we can draw on participant feedback which points to a difference in experience between the two groups. Participants found mindful eating a harder intervention to follow. Whilst we provided written instructions for the use of mindful eating, it may be that a more immersive experience (e.g., video or audio recordings) with opportunities for question and answers, would have increased the ease of intervention use.

The use of a web-based intervention meant reliance on individuals coming across recruitment information via social media, then completing the baseline survey on a voluntary basis. With COVID-19 related restrictions, this was the only viable form of administration. However, there are groups with known issues regarding digital literacy and accessibility to web-based research including some older adults, people with long-term health conditions or disabilities, and those without internet access. These groups are therefore likely to be under-represented in the present study. Furthermore, the present study recruited few male participants, which mirrors the pattern in weight management studies generally, where typically less than 30% of participants are male (Tsai and Wadden, 2005). Caution must therefore be exercised in generalizing findings of the present study to these groups, and consideration should be given as to how future research could recruit male participants, and therefore better account for the male experience. Male-only support groups seem to be effective (Young et al., 2012), especially those delivered virtually (Azar et al., 2015).

The results provide initial support for the use of remote interventions to help manage food cravings and associated emotional experiences. Participants reported that the food craving diary was easy to complete. Knowing that this is an accessible, easy, and effective intervention for the reduction of food cravings and related eating behavior could have wide reaching applications in the provision of remote healthcare. The need for healthcare to move to a blended form and better utilize technological resources is being increasingly recognized (Nicholls et al., 2016). The delivery of effective remote interventions such as those used in the present study has potential to expedite the provision of healthcare interventions. This is especially critical at a time when healthcare services worldwide are under pressure due to pandemic related reductions in service provisions (Brown et al., 2021).

CONCLUSIONS

Significantly less eating and better wellbeing were reported after both intervention conditions. The completion of a 7-day food craving diary was effective in reducing food cravings (i.e., frequency of craving experienced, giving into craving, and difficulty resisting), as well as the intensities of unpleasant emotions experienced at the time of the highest food cravings. Following mindful eating guidelines alongside a food diary for the same time period was no more effective than completion of the diary alone. Our findings highlight the need to consider ways to increase participant involvement and retention.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Wolverhampton Ethics Committee (Unique code: 01/20/AF1/UOW). The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

TD, C-HC-W, and MR: conceptualization and methodology. C-HC-W: data management. C-HC-W and MR: data curation. CR and MR: formal analysis. TD, C-HC-W, WN, and MR: writing – original draft. TD, C-HC-W, WN, JC, CR, JF-M, YC, and MR: writing – review and editing. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.903096/full#supplementary-material

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The Self-Regulation of Eating Attitudes in Sport Scale: Defining an Optimal Regulation Zone

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This study examines the hypothesis of a Zone of Optimal Regulation of Eating Attitudes in Sport (ZOREAS). The ZOREAS refers to a band, or zone within which athletes are most likely to optimize eating attitude regulation which should be associated with a low level of disordered eating. Scores outside this zone indicate a risk factor for eating disorders. One hundred and eleven volunteer athletes were recruited. Two variables were assessed: self-regulation of eating in sport, and eating attitudes and behaviors, measured with the French Self-Regulatory Eating Attitude in Sports Scale (SREASS), and the French version of the Eating Attitudes Test (EAT), respectively. Correlational analyses and an ANOVA were run. As expected, we observed a negative relationship between scores for the self-regulation of eating, and disordered eating attitudes in the sports context. To better-determine the ZOREAS, we ran a one-way ANOVA, which was significant for disordered eating attitudes. The plot of the interaction confirmed three trends: a high level of disordered eating attitudes (EAT scores over 20) is associated with a high level of self-regulation of eating attitudes (SREASS scores over 24); a medium level of disordered eating attitudes is associated with a low level of self-regulation of eating attitudes (SREASS scores under 19); a low level of disordered eating attitudes is associated with a medium level of self-regulation of eating attitudes (SREASS scores between 19 and 24). Thus, the ZOREAS was determined to be SREASS scores within the range 19–24. The ZOREAS may be useful to sports psychology practitioners who work with athletes.

Keywords: regulation of eating attitudes, sport, zone of optimal regulation, eating disorders, scale

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INTRODUCTION

Previous studies have defined behavioral self-regulation as the intentional control of attention, thoughts, emotions, behaviors, and the environment (Usher and Schunk, 2017; Baumeister et al., 2018). Self-regulation of eating attitudes is related to the individual's concerns about his or her body, the intensity of exercise and physical activities (Desharnais et al., 1986; McAuley and Mihalko, 1998), and the degree of engagement in weight loss and nutrition programs (see Herman and Polivy, 2004, for a review). Behavioral self-regulation can be improved with practice (Hofmann et al., 2012) and the ability to effectively regulate one's eating behavior is a major goal, not only for patients with an eating disorder, but also for individuals such as athletes. Although, in moderation, regulation is beneficial for the health of the athletes, the over-regulation of eating behavior can result in the person being underweight, or malnutrition. At the other extreme, a permanent failure to self-regulate eating may result in excess weight and obesity.

In the sport's context, Scoffier et al. (2010a) developed and validated the French Self-Regulatory Eating Attitude in Sports Scale (SREASS). Five subscales measure the control of eating with respect to: (a) food temptation, (b) negative affect, (c) social interaction, (d) lack of compensatory strategies, and (e) a lack of anticipation of consequences on performance. The sport context is defined by specific socialization agents like the coach and specific norms of excellence and accomplishment (Scoffier et al., 2010a). In sport context, the athletes are characterized by subclinical pathology or at high risk for eating disorders and the SREASS is not specifically designed for individuals with eating disorders, like anorexia and bulimia. The SREASS give the particularly high stakes and intense social pressures of this context.

At the same time, Pine et al. (1997) reported a relevant correlation between symptoms of conduct disorders during adolescence and obesity in early adulthood, attributed to common mechanisms underlying "impulsive aggression" and dysregulation of body weight and this finding corroborated results reported in many of the studies cited in AbuSabha and Achterberg's (1997) earlier review of the literature. For instance, the capacity for self-regulated eating was found to affect students' control of fruit and vegetable consumption (Baranowski et al., 1997), and to be negatively related to disordered eating in the sports context (Scoffier et al., 2010a,b). In sport context the authors (Scoffier et al., 2010a,b) related the self-regulation of eating attitude scale to the eating attitude test (EAT)—26 in French version (Leichner et al., 1994). The EAT-26 is a generic scale to diagnose eating disorders however it is no specific to the sport context it is useful in the sport context. The instruments developed for daily living seem limited and understand the eating behavior through a validated tool for athletes seems needed to better understand the eating disorders in this population and to develop effective strategies for prevention.

In the general population, the self-regulation of eating has been directly related to positive physical and mental health outcomes, as well as overall life satisfaction (e.g., Sharbafshaaer, 2019; Gupta and Verma, 2020). On the other hand, low self-regulation is associated with a high body mass index and obesity (Ruzanska and Warschburger, 2019). Individuals who binge tend to overeat, while those with anorexia nervosa are likely to drastically reduce their food intake (Kenny et al., 2017, 2019). The ability to effectively regulate one's eating behavior is a major goal, not only for patients with an eating disorder, but also for individuals engaged in dietary and weight-loss interventions (e.g., people who suffer from obesity). However, in previous articles higher eating self-regulation scores are a significant protective factor for a broad range of personal and interpersonal problems, and low self-regulation is a significant risk factor (e.g., Scoffier et al., 2010b). The contradiction between the higher eating self-regulation was observed in individuals with anorexia and the protective role of a higher eating self-regulation needs to be explored considering specifically the relationship between different level of self-regulation and disordered eating. Conversely, positive antecedents of disordered eating can eventually turn negative if taken too far. This can be characterized as the "too much of a good thing" effect (Pierce and Aguinis, 2013), which questions the unilateral goodness of self-regulation of eating attitudes. No research has investigated the curvilinear relationship between self-regulation of eating attitudes and disordered eating.

The literature defines two eating disorders, anorexia nervosa and bulimia nervosa, as the over- or under-control of socioemotional behaviors, respectively (Chen et al., 2015; Lynch et al., 2015). Disorders of over-control have been linked to social isolation, cognitive rigidity, highly-detail focused processing, a strong need for structure, and hyper-perfectionism (Lynch et al., 2015), traits that have also been found in individuals with orthorexia nervosa tendencies (Koven and Abry, 2015). It is possible that the latter individuals also suffer from poor emotional processing and regulation, and that orthorexic behaviors are used to regain control. Consequently, the aim of the present study was to identify optimal SREASS scores, a Zone of Optimal Regulation of Eating Attitudes in Sport (ZOREAS) and create categories which would be used by practitioners to identify athletes with attitudes associated with disordered eating. The categories would be based on the relationship between SREASS scores and EAT-26 scores. Scores outside the ZOREAS would indicate a risk factor for eating disorders.

MATERIALS AND METHODS

Participants

A priori power analysis has been used to determine the necessary sample size *N* on G*Power (Faul et al., 2007). The ideal sample size *N* calculated is 66 participants. One hundred and eleven volunteer athletes ($M_{age} = 22$; 51 years; $SD_{age} = 8.05$) were recruited. The participants were at least 16 years old. They were 50 male athletes and 61 female athletes. They were regular sport practitioners, and all of them were at least regional competitors. They trained about 8 h per week on average, with 43.7% training more than 10 h per week and all of them training minimum 3 h per week. Three types of sport, considered as at-risk for disordered eating (Petrie and Greenleaf, 2007) were the focus of the investigation: aesthetic ($N = 50$), endurance ($N = 36$) and weight category ($N = 25$). The Research Ethics Committee of the University Côte d'Azur approved all procedures (authorization number: 2021-011).

Background Information

At the beginning of the study, the following demographic data were collected: gender, age, sport type, and level of participation.

Self-Regulation of Eating Attitude in Sport

Self-regulation of eating attitudes in sports (**Appendix 1**) was assessed with the self-report SREASS questionnaire, developed, and validated in French by Scoffier et al. (2010a).

This tool is composed of five factors pertaining to the self-regulation of eating attitudes in the following contexts: (a) food temptation, (b) negative affect, (c) social interaction, (d) lack of compensatory strategies, and (e) a lack of anticipation of consequences on performance. Items are measured on a Likert-type scale that ranges from "not at all able" (1) to "completely able" (6). A global index of self-regulation of eating attitudes was calculated by summing responses to items on all five subscales. The internal consistency of the global scale was satisfactory ($\alpha = 0.88$).

The Eating Attitudes Test

Eating attitudes and behaviors were assessed with the French version of the Garner et al. (1982) Eating Attitudes Test (EAT, **Appendix 2**; Leichner et al., 1994). This 26-item self-report inventory comprises three subscales: dieting, bulimia, and oral control (e.g., "The desire to be thinner worries me"; "I cut up my food in small pieces"; "I vomit after eating") and is used with both adolescents and adults. Participants respond to items on a six-point Likert-type scale ranging from 1 (always) to 6 (never). In the present study, and consistent with previous work (Scoffier et al., 2010a), only a global measure of disordered attitudes was used, and scores were reversed for the analyses. Thus, a higher score indicated a more disordered eating attitude. This global scale exhibited satisfactory internal consistency ($\alpha = 0.86$).

Procedure

The two questionnaires were administered online and could be completed in under 20 min. Data were collected *via* the Lime Survey interface of the Université Côte d'Azur. All data were anonymous; participants were informed beforehand that they were not obliged to respond to every question, that this was not a test (i.e., there were no right or wrong answers), and that all responses would remain strictly confidential and only used for research purposes.

Analyses

Means, SDs, alpha coefficients, and bivariate correlations were calculated for the self-regulation of eating attitudes and the disordered eating variables. We adopted a procedure based on hierarchical linear regression analyses with self-regulation of eating attitudes on disordered eating, and a quadratic model (self-regulation of eating attitudes on disordered eating with the addition of a quadratic term) to determine the curvilinear relationship between the variables. An ANOVA was run to determine if there are self-regulation of eating attitudes' mean differences between the groups. Follow-up analyses examined simple main effects. Data were analyzed using SPSS version 22.

RESULTS

Descriptive statistics are presented in **Table 1**. Twenty-five participants scored over 20 on the EAT scale and were considered as susceptible to developing an eating disorder. The correlation matrix (Pearson's *r*; **Table 1**) highlighted a negative relationship between SREASS and EAT scores among the overall sample.

The above results confirmed previous findings that found a linear relationship between SREASS scores, and disordered eating attitudes (Scoffier et al., 2010a). Study found a linear relationship between self-regulation of eating attitudes and disordered eating indicating a consistent association ($\beta = 0.59$, $p < 0.001$). Additionally, self-regulation of eating attitudes showed a significant quadratic effect on disordered eating ($\beta = -4.38$, $p < 0.001$). The shape of the curves reflects the too much of a good thing effect (**Figure 1**).

To better-determine the ZOREAS, we ran a one-way ANOVA which was significant for disordered eating attitudes [F (30; 42.16) = 21.37, $p = 0.00$]. The plot of the interaction (cf., **Figure 2**) confirmed three trends: (i) a high level of disordered eating attitudes (EAT scores over 20) is associated with a high level of self-regulation of eating attitudes (SREASS scores over 24); (ii) a medium level of disordered eating attitudes is associated with a low level of self-regulation of eating attitudes (SREASS scores under 19); and (iii) a low level of disordered eating attitudes is associated with a medium level of self-regulation of eating attitudes (SREASS scores between 19 and 24). Thus, the ZOREAS was determined to be SREASS scores within the range 19–24. The ZOREAS has been colored in blue on the **Figure 2**.

DISCUSSION

This study examined the relationship between the self-regulation of eating attitudes in sport with a specific tool adapted to a population of athletes and disordered eating, using instruments useful to a population of athletes considering the literature. Consistent with our hypothesis, when we consider the global sample with correlational analysis, we observed an overall, negative linear relationship between self-regulatory eating attitudes and disordered eating in the sports context. This relationship confirmed the work of AbuSabha and Achterberg (1997) and demonstrated the protective character of self-regulated eating attitudes on disordered eating in a sport context. However, this study tried to investigate deeper the relationship between self-regulation of eating attitudes and disordered eating. First, the study allows us to observe that self-regulation of eating attitude increased with disordered eating down to a point and then leveled up. So, this step reflects the too much of

TABLE 1 | Descriptive statistics and *post-hoc* tests.

	N	*M*	SD	*r*
SREASS	111	19.92	3.84	−0.53*
EAT	111	14.84	9.36	–

*r is the correlation between SREASS and EAT scores. *p < 0.05.*

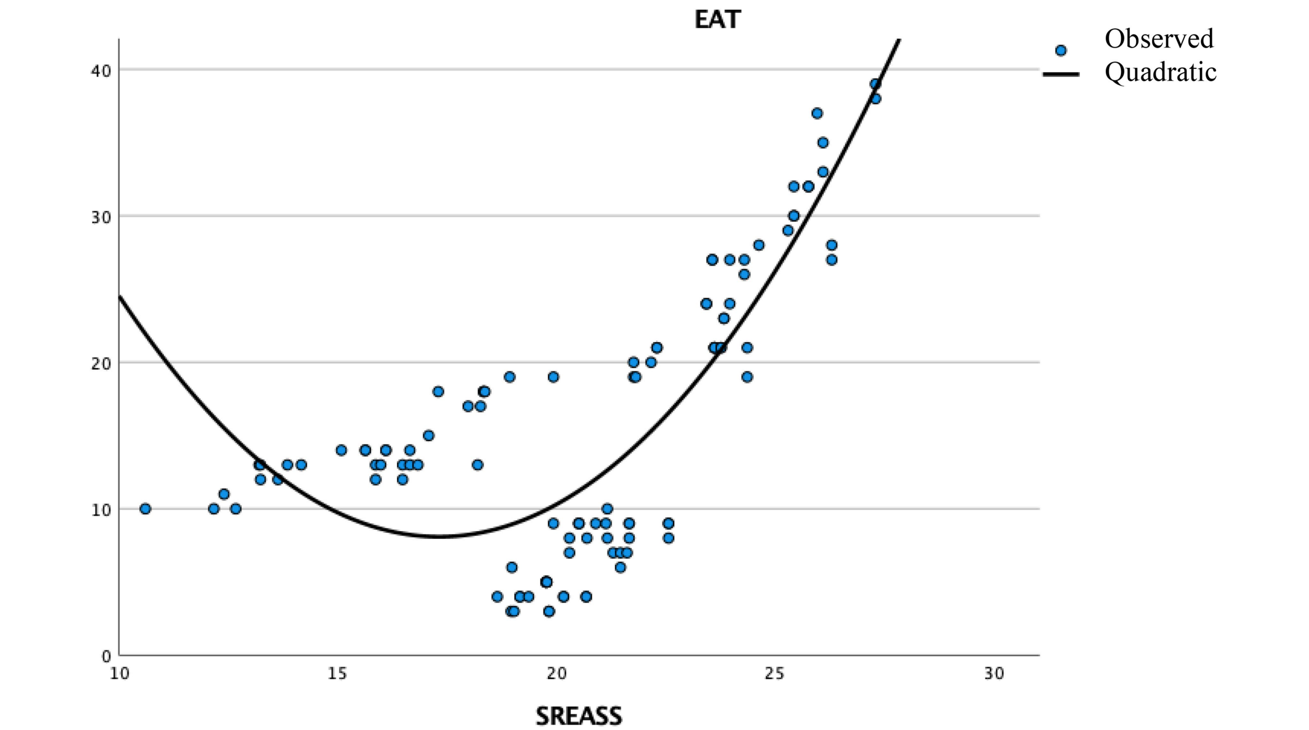

FIGURE 1 | Curvilinear relations between self-regulation of eating attitudes and disordered eating.

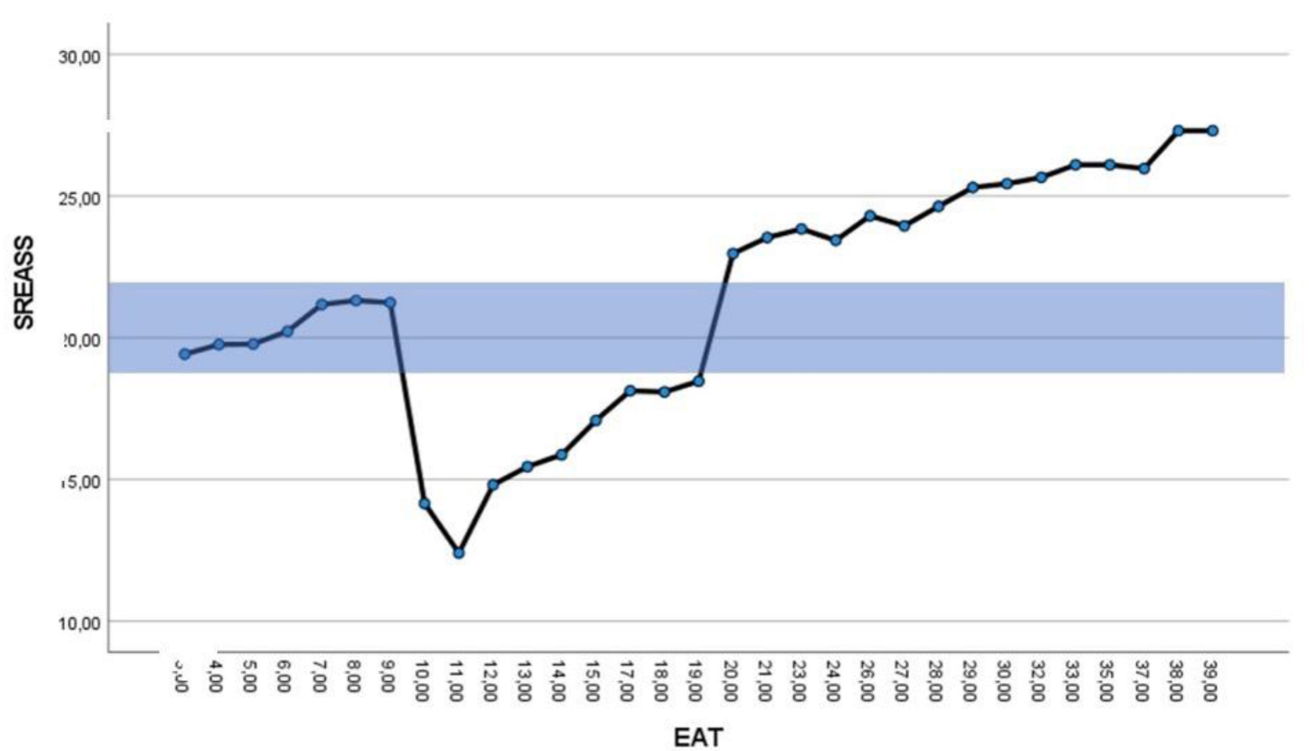

FIGURE 2 | Plot of the interaction between Eating Attitudes Test (EAT) and Self-Regulatory Eating Attitude in Sports Scale (SREASS) scores. X-axis refers to EAT scores and the Y-axis refers to SREASS scores.

a good thing effect. The study also tested the hypothesis of the existence of a ZOREAS and revealed that the overall relationship between self-regulatory eating attitudes and disordered eating was not totally linear. This latter finding confirms the definition of disordered eating given in Lynch et al. (2015) or Chen et al. (2015), which considers that eating disorders relate to the over- or under-control of socioemotional behaviors. Specifically, our analyses identified a ZOREAS, characterized by SREASS scores between 19 and 24 and EAT scores very low (<10). The concept of the ZOREAS is not well-documented in the literature, and our study is the first of its kind. Based on this study, the SREASS and the ZOREAS seems to be an interesting tool for determining disordered eating risk.

Perspectives

Future longitudinal studies could determine the stability and the specificity of the ZOREAS, while an experimental study would help to establish the direction of causality suggested by our correlational analysis. Most importantly, this type of research would help in developing educational programs based on self-regulation of eating attitude adaptation that seek to limit the emergence of disordered eating among athletes. Our study has several limitations that need to be considered. First, data were self-reported, and could be biased by social desirability. Second, correlation analyses were used, which limits the generalization of the demonstrated relationships between variables (i.e., the self-regulation of eating attitudes and disordered eating). Third, the ZOREAS could be compared to the *individual zone of optimal functioning* (Hanin, 2000), and like the latter, could vary according to the sport and the individual. Future studies could investigate the individual ZOREAS considering the eating behaviors and the performance in a longitudinal design.

Applications for Professionals

The ZOREAS may be useful to sports psychology practitioners who work with athletes. For instance, it could provide a more holistic understanding of the degree of self-regulation of the athletes and in consequence influence how, in general, athletes manage their eating attitude in the context of their chosen sport. The ZOREAS cannot be used as a measure to determine ability to change eating strategies, but it can be used as a tool to determine if someone should change eating strategies. So, it could be used to evaluate an athlete's ability to engage in new, and better-adapted eating strategies, and to determine whether the development of new eating attitudes would benefit performance outcomes.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Université Côte d'Azur Ethics Committee authorization number: 2021-011. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

SS-M defined the project and realized the data collection. SS-M and YP worked on the analyses and the manuscript. All authors contributed to the article and approved the submitted version.

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APPENDICES

Appendix 1 | Self-regulation of eating attitudes in sport scale (SREASS).

1. Te sens-tu capable de manger un gâteau sans penser aux conséquences que cela va pouvoir avoir pour ta prochaine compétition? *(Do you feel capable of eating a dessert without thinking of the consequences this may have on your next competition?)*
2. Te sens-tu capable d'aller te faire vomir si tu as mangé du gâteau d'anniversaire à une fête? *(Do you feel capable of making yourself vomit if you have just eaten cake at a birthday celebration?)*
3. Te sens-tu capable de contrôler ce que tu manges quand de la nourriture alléchante est. devant toi? *(Do you feel capable of controlling what you eat when tempting food is put before you?)*
4. Te sens-tu capable de contrôler ce que tu manges quand il y a beaucoup de nourriture disponible pour toi? *(Do you feel capable of controlling what you eat when a lot of food is easily available?)*
5. Te sens-tu capable de contrôler ce que tu manges quand tu es anxieux(se) ou inquiet(e)? *(Do you feel capable of controlling what you eat when you are anxious or worried?)*
6. Te sens-tu capable de contrôler ce que tu manges quand tu es irritable? *(Do you feel capable of controlling what you eat when you are irritable?)*
7. Te sens-tu capable de manger avec tes partenaires d'entraînement et ne pas te priver? *(Do you feel capable of eating with your training partners without depriving yourself?)*
8. Te sens-tu capable de manger des frites sans penser aux conséquences que cela va pouvoir avoir sur tes performances? *(Do you feel capable of eating french fries without thinking of the consequences this may have on your performance?)*
9. Te sens-tu capable de ne rien manger à un repas sous prétexte de la présence de ton entraîneur? *(Do you feel capable of eating nothing at a meal using the pretext that your coach is present?)*
10. Te sens-tu capable de contrôler ce que tu manges quand tu es déprimé(e)? *(Do you feel capable of controlling what you eat when you are depressed?)*
11. Te sens-tu capable de manger des sucreries sans penser aux conséquences que cela va pouvoir avoir sur ta prochaine compétition? *(Do you feel capable of eating sweets without thinking of the consequences this may have on your next competition?)*
12. Te sens-tu capable de manger en grosse quantité sans penser aux conséquences que cela va pouvoir avoir sur tes performances? *(Do you feel capable of a lot of food at a time without thinking of the consequence this may have of your performance?)*
13. Te sens-tu capable de manger trois repas par jour sans te faire vomir, pratiquer de l'exercice excessif, prendre des diurétiques ou des laxatifs? *(Do you feel capable of eating three meals a day without making yourself vomit, exercise to excess, or take diuretics or laxatives?)*
14. Te sens-tu capable de manger de la nourriture riche en graisses sans te faire vomir, pratique de l'exercice excessif, prendre des diurétiques ou des laxatifs? *(Do you feel capable of eating high-fat foods without making yourself vomit, exercise to excess, or take diuretics or laxatives?)*
15. Te sens-tu capable de prendre un repas avec tes parents en mangeant en quantité normale? *(Do you feel capable of eating a normal amount of food when you have a meal with your parents?)*
16. Te sens-tu capable de résister à la tentation de sucreries que tu apprécies beaucoup? *(Do you feel capable of resisting the sweet foods that you like the most?)*

Inversed items: 2 and 9.

Appendix 2 | Eating attitudes test 26 (Garner et al., 1982).

1. I am terrified about being overweight.
2. I avoid eating when I am hungry.
3. I find myself preoccupied with food.
4. I have gone on eating binges where I feel that I may not be able to stop.
5. I cut my food into small pieces.
6. I aware of the calorie content of foods that I eat.
7. I particularly avoid food with a high carbohydrate content (i.e., bread, rice, potatoes, etc.).
8. I feel that others would prefer if I ate more.
9. I vomit after I have eaten.
10. I feel extremely guilty after eating.
11. I am occupied with a desire to be thinner.
12. I think about burning up calories when I exercise.

13. I other people think that I am too thin.
14. I am preoccupied with the thought of having fat on my body.
15. I take longer than others to eat my meals.
16. I avoid foods with sugar in them.
17. I eat diet foods.
18. I feel that food controls my life.
19. I display self-control around food.
20. I feel that others pressure me to eat.
21. I give too much time and thought to food.
22. I feel uncomfortable after eating sweets.
23. I engage in dieting behavior.
24. I like my stomach to be empty.
25. I have the impulse to vomit after meals.
26. I enjoy trying new rich foods.

Inversed item: 26.

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The relationship between Big Five Personality Traits, eating habits, physical activity, and obesity in Indonesia based on analysis of the 5th wave Indonesia Family Life Survey (2014)

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This study investigated the association between Big Five Personality Traits (Openness to new experience, Conscientiousness, Extraversion, Agreeableness, Neuroticism) and nutrition-related variables (eating habits, physical activity, and obesity using Body Mass Index). We used secondary data from the Indonesia Family Life Survey (IFLS) wave 5 involving a total of 14,473 men and 16,467 women aged 15–101 years (mean = 37.34; *SD* = 14.916) in Indonesia that was selected by stratified random sampling conducted in the period 2014 to 2015. Data were collected through interviews with the Big Five Index 15 and a questionnaire similar to the Global Physical Activity Questionnaire which was translated into the Indonesian language, and based on measurements of height and weight. Analyses used binary logistic regression test controlled by socio-demographic factors (age, gender, education, occupation, and marital status) to determine the association between Big Five Personality Traits and eating habits (recommended and non-recommended foods), physical activity, and obesity. Results showed that openness and extraversion were positively associated with recommended and non-recommended foods, conscientiousness was positively associated with only recommended foods, agreeableness was positively associated with recommended foods, and negatively associated with only one non-recommended food. Whereas, neuroticism was positively associated with non-recommended foods and negatively associated with recommended foods. Openness ($p = 0.010$; OR = 1.015; 95% CI = 1.004–1.027) and conscientiousness ($p < 0.001$; OR = 1.045; 95% CI = 1.030–1.059) were associated with physical activity. Conscientiousness ($p = 0.002$; OR = 1.025; 95% CI = 1.009–1.041), extraversion ($p < 0.001$; OR = 1.079; 95% CI = 1.065–1.092), and neuroticism ($p < 0.001$; OR = 0.966; 95% CI = 0.953–0.978) were associated with obesity. Although some results were different from previous studies, these associations can be used as strategies of behavioral change due to the adaptation of personality characteristics, which can be modified even though the personality tends to be persistent. Further studies are needed to understand other mechanisms that might underlie this association.

KEYWORDS

Big Five Personality Traits, physical activity, obesity, Body Mass Index, Indonesia, eating habits

Introduction

Individuals need to maintain their health by showing healthy behavior in order to avoid various health problems. Poor eating habits can have a negative effect on an individual's nutritional status (Indonesian Ministry of Health [IMH], 2017); furthermore, a study published by The Lancet journal found that the food consumed daily was the leading cause of death compared to smoking and now has become one of the five causes of death worldwide (Indonesian Ministry of Health [IMH], 2019). Moreover, lack of physical activity is also a major risk factor for chronic diseases and premature death due to non-communicable diseases (World Health Organization [WHO], 2018), although regular physical activity can not only decrease the risk of various diseases but also can improve mental health and quality of life (World Health Organization [WHO], 2018).

Personality is a dynamic and complex physical and psychological system within the individual that underlies every behavior (Ahdiyana, 2011; Riadi, 2012). Personality can be associated with several health conditions that can be explained by personality-related behavioral factors (Tiainen et al., 2013). As one of the personality theories that is often used, the Big Five Personality Traits or Five-Factor Model (FFM) developed by Costa and McCrae (1985) divided human personality into five major dimensions: Agreeableness (A), Extraversion (E), Neuroticism (N), Conscientiousness (C), and Openness to experience (O) (Feist et al., 2013), which were associated with several health-related behaviors.

Previous studies found an association between personality, particularly Big Five Personality Traits with nutrition-related behaviors (such as eating habits and physical activity) and nutritional status, but most of these studies were conducted in Western countries, such as the study by Sutin et al. (2011) conducted in America, Terracciano et al. (2009) in Italy, Intiful et al. (2019) in Ghana, the study by Tiainen et al. (2013) were conducted on people born in Helsinki, Finland, the meta-analysis by Sutin et al. (2016) consisting of the United States, England, and Japan, and many other studies. Similar to the significant cross-cultural differences between Western and Eastern countries, research conducted in Indonesia, one of the Eastern countries, was scarcely found in a peer-reviewed article. The studies given in literature suggested a relationship between Big Five Personality Traits and eating behavior or food choices, for example in a study of 288 students (121 males and 167 females) of *Institut Pertanian Bogor* aged 16–18 years old, the multiple linear regression test results showed that extraversion who enjoys socializing ($\beta = 0.163$; $p = 0.035$), openness to experience who has creative and imaginative nature ($\beta = 0.208$; $p = 0.013$), and agreeableness who has friendly and environmentally sensitive nature ($\beta = 0.265$; $p = 0.009$) tend to choose to eat vegetables for various reasons (Purnamawati and Yuliati, 2016). In another study of 380 students of *Universitas Islam Negeri Suska Riau* aged 18–21 years old, the multiple regression test results showed conscientiousness (rxy = −1.230; $p = 0.008$) and neuroticism (rxy = 0.103; $p = 0.022$) was related to eating behavior (Nelvi, 2016). Additionally, extraversion was related to restrained eating, agreeableness was related to external and emotional eating, and openness to experience was related to emotional, external, and restrained eating (Nelvi, 2016). A study of 195 students (128 males and 67 females) at several universities in South Tangerang linked the Big Five Personality Traits to healthy behavior, one of which was eating behavior, the multiple regression test results showed that personality as a whole did not have a significant influence on healthy behavior, but only openness ($p = 0.018$; $B = 0.228$) and openness among females ($p = 0.002$; $B = 0.401$) had a significant positive effect on healthy behavior based on the regression coefficient (Rahmadian, 2011). Unfortunately, in this study, health behavior (including eating behavior, exercise, smoking, and alcohol consumption) was measured as one, so there was no visible influence from the other four personalities that might only affect certain healthy behaviors (Rahmadian, 2011). As far as we could find, there were no studies that linked physical activity and nutritional status to Big Five Personality Traits in the Indonesian setting and these studies were conducted with a sample size of less than 400 respondents.

For this reason, we conducted this study, especially since evidence related to the association between personality traits, eating habits, physical activity, and nutritional status was scarcely found in a peer-reviewed article in the Indonesian setting and this research was also conducted using secondary data analysis from the Indonesia Family Life Survey (IFLS) with a sample size of tens of thousands, so the results obtained in this study should better describe the existing situation. Therefore, this study aimed to analyze the relationship between Big Five Personality Traits, eating habits, physical activity, and obesity in Indonesia.

Materials and methods

Indonesia family life survey

Data collection

This study used a quantitative analytic cross sectional design from secondary data analysis of the 2014 Indonesia Family Life Survey (IFLS) or the 5th wave IFLS. IFLS represented about 83% of the Indonesian population (13 out of 26 provinces) in 1993 which was the result of collaboration between the non-profit RAND corporation and Survey Meter (Strauss et al., 2016). IFLS was a continuous longitudinal socio-economic and health survey based on a household sample and had been carried out 5 times, IFLS1 (1993–1994), IFLS2 (1997–1998), IFLS3 (2000), IFLS4 (2007–2008), and IFLS5 (2014–2015) (Strauss et al., 2016).

Since IFLS was a continuous longitudinal survey, the sampling scheme of the first wave will determine the next wave. IFLS used a stratified random sampling technique where the sampling scheme was conducted randomly by the province to maximize population representation and capture the cultural and socio-economic diversity of Indonesia based on the Susenas (National Socioeconomic Survey) in 1993 whose sampling frame was designed by the BPS (Central Bureau of Statistics) based on the 1990 census (Frankenberg and Karoly, 1995). There were 321 EAs (Enumeration Areas) which were randomly selected from each of the 13 provinces with details of the sampling rate applied to each province and resulted in a total EA distribution, and separated by sampling urban EAs and EAs in small provinces to facilitate urban-rural and Javanese-non-Javanese comparisons (Frankenberg and Karoly, 1995). In the selected EA, households were randomly selected based on the 1993 Susenas list, giving a total of 7,730 target sample households, and complete/partial interviews were obtained for 7,039 households, including 22,327 successfully interviewed individuals in IFLS1 (Frankenberg and Karoly, 1995).

In IFLS5, re-contact was established with respondents sampled since IFLS1 in 1993 with a re-contact rate of 92% of original IFLS1 dynasty households (Strauss et al., 2016). IFLS5 was conducted on the same set of households in the previous wave and the same IFLS distribution of 16,204 households and 50,148 individuals were interviewed with 2,662 people who had died since IFLS4 being interviewed with representatives who knew them well (Strauss et al., 2016).

Participants

Participants in this study were selected from all people aged $\geq$ 15 years taken from the IFLS5 dataset. They were chosen, as the information on certain study variables (eating habits and physical activity) was available only to them. From a total of 50,148 participants successfully interviewed on IFLS5, 19,208 participants (38%) were excluded from the study because they were under 15 years old and provided incomplete information regarding the required variables. If a value was missing or answered "don't know" in one of the studied variables, the respondent would be excluded from the study. Therefore, 30,940 participants (53.2% female) aged 15–101 years in Indonesia were included in this study. The mean age was 37.34 years (SD = 14.916).

Variables and measures

Data was collected using Computer Assisted Personal Interviewing (CAPI) system. This system that uses computers to manage survey questionnaires (all in the Indonesian language) so that interviewers can directly enter data during face-to-face interviews (Strauss et al., 2016). The independent variable studied in this study was personality based on the Big Five Personality Traits. Variables related to socio-demographic characteristics were used as control variables. Whereas, the dependent variables studied were eating habits (recommended and non-recommended foods), physical activity, and obesity based on BMI.

Socio-demographic factors

The socio-demographic factors used in this study were age (continuous variable), gender, education (not attending school or attending school), occupation (unemployed, self-employed, or worker), and marital status (never married, married/living together, or divorced/separated). The occupation was defined as the respondent's primary employment status (Strauss et al., 2016). All these variables were obtained through interviews (Strauss et al., 2016).

Big five personality traits

Personality data were obtained through interviews (Strauss et al., 2016). The question used was the Big Five Index 15 (BFI 15), a subset of BFI 44 from John and Srivastava (1999), which consisted of 15 traits representing all five personality dimensions (openness to new experience, conscientiousness, extraversion, agreeableness, neuroticism) with three traits for each personality dimension (Strauss et al., 2016). A short version of BFI, a 15-item instrument, used to measure personality dimensions, was first made available to SOEP (Socio-Economic Panel) in 2005 (Dehne and Schupp, 2007). This instrument was used in many large-scale surveys, such as the German Socio-Economic Panel (GSOEP) (Strauss et al., 2016). The BF1 15 instrument was translated into Indonesian and back into English several times until the English re-translation converged with the BFI 15 English (Strauss et al., 2016). Four lists of the same 15 words were made and the list used was randomly determined in CAPI (Strauss et al., 2016). A five-point ordinal scale was used to represent how well the respondent believes that the trait represents them, 1 = disagree strongly, 2 = disagree a little, 3 = neither agree nor disagree, 4 = agree a little, and 5 = agree strongly (Strauss et al., 2016). In question (R) (reverse), the value was given in reverse from 5 to 1 (John et al., 1991). Scores on each personality were summed based on the five personality dimensions.

We tested the validity and reliability of the BFI 15 scale using SPSS version 20 with 30,940 respondents based on the number of samples that would be used in this study. Item validity was seen through the value of each item with Pearson product-moment. Items were considered valid if the significance value was $p < 0.05$. Based on these criteria, all item validity test results were considered valid. Meanwhile, the reliability test was performed using an internal consistency approach which was analyzed using the Cronbach Alpha formula. The determination of the high and low-reliability coefficient was based on Guilford's reliability coefficient classification (Sugiyono, 2011). The result of the reliability test showed that the alpha coefficient value was 0.402. Based on Guilford's reliability coefficient classification, a coefficient value of more than 0.40 to 0.70 means the variable has sufficient reliability category. Therefore, the scale was reliable enough to be used.

Eating habits

Eating habits data were obtained through interviews (Strauss et al., 2016). The foods were representative of foods rich in iron and vitamin A, two micronutrients considered deficient among the Indonesian population, and also include fast foods, fried foods, and sweet snacks to get at some unhealthy eating habits (Strauss et al., 2016). Eating habits were defined as the consumption frequency (number of days) by food type (17 types) in the past week which could be answered by never or between 1 to 7 days which were then classified as not consuming (answered never) and consuming (answered between 1 to 7 days) in this study. The 17 types of food were sweet potatoes, eggs, fish, meat (beef, chicken, pork, etc.), dairy, green leafy vegetables, banana, papaya, carrot, mango, *sambal*, rice, including five non-recommended foods were instant noodle, fast food, soft drink (coca cola, sprite, etc.), fried snacks (*tempe, tahu, bakwan*, etc.), and sweet snacks (*wajik, geplak*, donuts, wafers, chocolate, etc.).

Physical activity

Physical activity data were obtained through interviews with a set of questions that were taken from an international survey on physical activities about the types and times of physical activities carried out in all parts of life (at work, home, and exercise) for at least 10 min continuously in the last 7 days (Strauss et al., 2016). The questionnaire consisted of similar questions as GPAQ but was simpler and translated into Indonesian, therefore the calculation and classification of physical activity were based on GPAQ (Global Physical Activity Questionnaire). However, because in the questionnaire activity duration was only asked for in a time frame, we chose the closest number from that time frame so that METs-minutes/week could be calculated. Respondents who answered < 30 min were counted as 15 min, ≥ 30 min counted as 60 min, < 4 h counted as 3 h (180 min), and ≥ 4 h counted as 5 h (300 min). In this study, the classification of high and moderate levels of physical activity based on reference values (GPAQ Analysis Guide Version 2 by World Health Organization [WHO], 2005) were grouped into one in high and moderate. Therefore, the level of physical activity was then classified into high and moderate, and low.

Obesity

To obtain BMI, the required height data were obtained through measurement using a Seca plastic height board, model 213, measured to the nearest millimeter, meanwhile, body weight was measured using a Camry model EB1003 digital scale, measured to the nearest tenth (one decimal point) of a kilogram (Strauss et al., 2016). Obesity of respondents aged ≥ 19 years was determined by BMI and < 19 years was determined by BMI-for-age (BMI/A) using WHO Anthro plus software. The cut-off point used refers to the regulation of the Indonesian Ministry of Health which was based on the WHO reference 2007 for children aged 5 to 18 years (Regulation of the Indonesian Ministry of Health number 2 of 2020 Indonesian Ministry of Health [IMH], 2020) and based on the FAO/WHO provisions where for the benefit of Indonesia, the cut-off point was modified based on clinical experience and research results in several developing countries to determine the BMI of individuals aged > 19 years (Regulation of the Indonesian Ministry of Health number 41 of 2014 Indonesian Ministry of Health [IMH], 2014). In this study, the classification of overweight and obesity based on reference values were grouped into one as obese. Therefore, obesity was categorized into: not obese for BMI: ≤ 25.0 and BMI/A: $\leq +1$ SD and obese for BMI: > 25.0 and BMI/A: $> +1$ SD.

Data analysis

The data that had been collected were tabulated and then tested for statistical correlation with binary logistic regression. First, the bivariate test was conducted between personality (each personality dimension based on the Big Five Personality Traits) and nutrition-related variables (eating habits, physical activity, and obesity), then continued with a multivariate test controlled by socio-demographic factors (sex, age, marital status, education, and occupation) conducted on significant variables in the bivariate test to examine the independent effect of personality. The covariates were predetermined based on previous studies that showed a confounding effect on the relationship between the studied variables (Terracciano et al., 2009; Kye and Park, 2012; Mõttus et al., 2013; Tiainen et al., 2013; Sutin and Terracciano, 2015a,b; Sutin et al., 2016; Gustavsen and Rickertsen, 2019; Pfeiler and Egloff, 2020). To examine whether the association between personality traits and nutrition-related variables varied by sex or age group (adolescent, adult, elderly), we also tested this interaction, controlling for socio-demographic factors. Data analysis was carried out using Statistical Package for the Social Sciences (SPSS version 20). A significance level of 95% and an error rate of $\alpha = 5\%$ (0.05). Significant relationships between the tested variables were determined if the $p < 0.05$.

Ethical considerations

This study using secondary data analysis was granted ethical clearance by the Airlangga University Faculty of Dental Medicine Health Research Ethical Clearance Commission.

Results

Descriptive statistics

The total sample in this study included 30,940 respondents. All characteristics of study participants are presented in **Tables 1, 2**.

Of the 30,940 respondents aged 15–101 years, most were women (53.2%), adults (85.8%), married/living together (72.6%), attending school (96.2%), and working (45.2%), and the mean age was 37.34 years ($SD = 14.916$). Most of them consumed animal protein in the form of eggs, fish, and meat, rice as carbohydrate sources, green leafy vegetables, banana, *sambal,* and three non-recommended foods: fried snacks, instant noodles, and sweet snacks. Meanwhile, most of them did not consume dairy as animal protein sources, sweet potatoes as carbohydrate sources, papaya, mango, carrot, and two non-recommended foods: fast food and soft drink. Respondents mainly consumed rice (99.8%) and did not consume fast food (88.9%). Most of the respondents had moderate and high levels of physical activity (55.2%) which was consistent with their nutritional status, most of them were classified as not obese (68.5%).

Table 2 shows that among the five dimensions of the Big Five Personality Traits, the dimension with the highest average score is agreeableness (11.70 ± 1.533). Meanwhile, the dimension with the lowest average score is neuroticism (8.04 ± 1.996).

TABLE 1 Characteristic of study participants.

Characteristics	Frequency (*n*)	Percentages (%)
Gender		
Male	14,473	46.8
Female	16,467	53.2
Age		
Adolescent (15–18 years)	2,868	9.3
Adult (19–65 years)	26,553	85.8
Elderly (>65 years)	1,519	4.9
Marital status		
Married/living together	22,459	72.6
Divorced/separated	2,378	7.7
Never married	6,103	19.7
Education		
Not attending school	1,191	3.8
Attending school	29,749	96.2
Occupation		
Unemployed	8,407	27.2
Self-employed	8,548	27.6
Worker	13,985	45.2
Eating habits Sweet potatoes		
Not consuming	20,061	64.8
Consuming	10,879	35.2
Eggs		
Not consuming	5,342	17.3
Consuming	25,598	82.7
Fish		
Not consuming	6,097	19.7
Consuming	24,843	80.3
Meat (beef, chicken, pork, etc.)		
Not consuming	11,559	37.4
Consuming	19,381	62.6
Dairy		
Not consuming	21,201	68.5
Consuming	9,739	31.5
Green leafy vegetables		
Not consuming	3,691	11.9
Consuming	27,249	88.1
Banana		
Not consuming	15,007	48.5
Consuming	15,933	51.5
Papaya		
Not consuming	22,933	74.1
Consuming	8,007	25.9
Carrot		
Not consuming	19,996	64.6
Consuming	10,944	35.4
Mango		
Not consuming	20,401	65.9
Consuming	10,539	34.1
Instant noodle		
Not consuming	10,555	34.1
Consuming	20,385	65.9

(Continued)

TABLE 1 (Continued)

Characteristics	Frequency (*n*)	Percentages (%)
Fast food		
Not consuming	27,506	88.9
Consuming	3,434	11.1
Soft drink (Coca cola, sprite, etc.)		
Not consuming	24,922	80.5
Consuming	6,018	19.5
Sambal		
Not consuming	5,877	19.0
Consuming	25,063	81.0
Fried snacks (*tempe, tahu, bakwan*, etc.)		
Not consuming	10,777	34.8
Consuming	20,163	65.2
Rice		
Not consuming	53	0.2
Consuming	30,887	99.8
Sweet snacks (*wajik, geplak*, donuts, wafers, chocolate, etc.)		
Not consuming	14,642	47.3
Consuming	16,298	52.7
Physical Activity		
Low	13,872	44.8
Moderate and high	17,068	55.2
Obesity		
Not obesity	21,207	68.5
Obesity	9,733	31.5

TABLE 2 Characteristic of study participants based on Big Five Personality Traits.

Big Five Personality Traits	Mean ± SD (min-max)
Openness	11.11 ± 2.006(3-15)
Conscientiousness	11.45 ± 1.656(3-15)
Extraversion	10.33 ± 1.998(3-15)
Agreeableness	11.70 ± 1.533(3-15)
Neuroticism	8.04 ± 1.996(3-15)

Regression results

To examine the relationship between personality (each personality dimension based on the Big Five Personality Traits) and nutrition-related variables (eating habits, physical activity, and obesity), statistical tests were performed using binary logistic regression due to the large sample size, the data were not normally distributed, and assumption of proportional odds was not met. Supplementary Tables 1, 2 present the regression results on the bivariate test for each variable tested in this study.

From the eating habits of 17 types of food tested, including five non-recommended foods: instant noodles, fast food, soft drink (coca cola, sprite, etc.), fried snacks (*tempe, tahu, bakwan*, etc.), and sweet snacks (*wajik, geplak*, donuts, wafers, chocolate, etc.), Supplementary Table 1 shows that openness and extraversion had a significant association with eating habits of all food types except rice. Conscientiousness was associated with eating all food types except mango, rice, and two non-recommended foods (instant noodle and fried snacks). Agreeableness was associated with eating fish, green leafy vegetables, fruits (banana, papaya, mango), carrot, and four of the five non-recommended foods (fast food, soft drink, fried snacks, and sweet snacks). Meanwhile, neuroticism was unrelated to eating eggs, fish, *sambal*, and rice. Therefore, only rice consumption did not have a significant association with all dimensions of Big Five Personality Traits. In addition, the eating habit of green leafy vegetables, bananas, papaya, carrot, fast food, soft drink, and sweets snacks were associated with all dimensions of the Big Five Personality Traits.

There was also a statistically significant association between the level of physical activity with openness (p = 0.007), conscientiousness ($p < 0.001$), and agreeableness (p = 0.008). Conscientiousness was 1.070 times more likely to have more high physical activities than agreeableness (OR = 1.020; 95% CI = 1.005−1.035) and openness (OR = 1.016; 95% CI = 1.004−1.027). There was also a statistically significant association between obesity and conscientiousness ($p < 0.001$), extraversion ($p < 0.001$), and neuroticism ($p < 0.001$). Extraversion was 1.093 times more likely to be obese than conscientiousness (OR = 1.052; 95% CI = 1.037−1.068). Meanwhile, neuroticism has a protective effect on obesity (OR = 0.977; 95% CI = 0.965−0.989). Next step, a multivariate test controlled with socio-demographic factors (sex, age, marital status, education, and occupation) was conducted on the significant variables in the bivariate test to examine the independent effect of personality.

Supplementary Table 2 shows that there was still a statistically significant association between all food types tested with openness even after controlling for socio-demographic factors, which meant that openness was associated with both recommended and non-recommended foods. All food types showed a positive association, which meant respondents with a higher openness were more likely to consume the tested food type than those with a lower openness. The highest possibility was found in green leafy vegetables (OR = 1.107; CI = 1.088−1.126) and the lowest was in fried snacks (OR = 1.019; CI = 1.007−1.031). In addition, only sweet snacks where all control variables had a significant correlation with the association between openness and eating habits according to the food type.

Openness was also positively associated in adults for all food types tested, except eggs, meat, dairy, green leafy vegetables, fast food, and sweet snacks did not vary by age group. The association was stronger in the elderly between openness with sweet potatoes (OR = 1.067; CI = 1.020−1.117), fish (OR = 1.112; CI = 1.058−1.168), and instant noodle (OR = 1.070; CI = 1.022−1.121) than in adults ([OR = 1.030; CI = 1.017−1.043]; [OR = 1.053; CI = 1.037−1.070], [OR = 1.056; CI = 1.042−1.070]), but no association was found in adolescents and the rest food types were not associated in adolescents and the elderly. In addition, the relationship between openness and all food types tested did not vary by sex, except fried snacks in males (OR = 1.026; CI = 1.008−1.044), and no association was found in females.

Supplementary Table 3 shows that after controlling for socio-demographic factors, only three non-recommended foods (fast food, soft drink, and sweet snacks) had no statistically significant association, while the others were positively associated with conscientiousness. The highest possibility was found in the green leafy vegetables (OR = 1.101; CI = 1.079−1.124) and the lowest was in sweet potatoes (OR = 1.018; CI = 1.003−1.032). Only meat where all control variables had a significant correlation with the association between conscientiousness and eating habits according to the food type.

Conscientiousness was also found to be positively related to all food types tested in adults, except green leafy vegetables, fast food, soft drink, and sweet snacks did not vary by age group. The results also showed that conscientiousness was related to fish (OR = 1.056; CI = 1.008−1.106), meat (OR = 0.949; CI = 0.909−0.991), banana (OR = 1.049; CI = 1.007−1.093), and *sambal* (OR = 0.939; CI = 0.892−0.988) in adolescents and eggs (OR = 1.073; CI = 1.008−1.042), dairy (OR = 1.143; CI = 1.065−1.226), and papaya (OR = 1.075; CI = 1.006−1.148) in the elderly. The association between conscientiousness and all food types tested did not vary by sex, except dairy (OR = 1.051; CI = 1.028−1.074) and fast food (OR = 1.046; CI = 1.011−1.082) in males and soft drink in females (OR = 0.968; CI = 0.942−0.994).

Supplementary Table 4 shows that after controlling for socio-demographic factors, only fish had no statistically significant association, while the others were positively associated with extraversion, which meant that extraversion was associated with both recommended and non-recommended foods. The highest probability was found in fast food (OR = 1.081; CI = 1.062−1.101) and the lowest was in sweet potatoes, mango, and instant noodle (OR = 1.023; CI = 1.011−1.036). Only sweet snacks where all control variables had a significant correlation with the association between extraversion and eating habits according to the food type.

Extraversion was also positively associated in adults for all food types tested, except meat, dairy, and sweet snacks, which did not vary by age group. The relationship between extraversion and all food types tested did not vary by sex, except sweet potatoes (OR = 1.034; CI = 1.018−1.051), carrot (OR = 1.043; CI = 1.027−1.060), and mango (OR = 1.029; CI = 1.013−1.046) in females, also, no association was found in males. However, the results showed that this relationship was stronger in females for eggs (OR = 1.065; CI = 1.043−1.087), meat (OR = 1.081; CI = 1.063−1.098), dairy (OR = 1.058; CI = 1.040−1.076), green leafy vegetables (OR = 1.041; CI = 1.016−1.066), instant noodle (OR = 1.026; CI = 1.009−1.043), fast food (OR = 1.092; CI = 1.066−1.118), soft drink (OR = 1.067; CI = 1.043−1.091), *sambal* (OR = 1.068; CI = 1.047−1.089), fried snacks (OR = 1.026; CI = 1.009−1.042), and sweet snacks (OR = 1.044; CI = 1.028−1.061) than in males. This showed that higher extraversion in females was more likely to consume all kinds of healthy and unhealthy foods than males.

Supplementary Table 5 shows that after controlling for socio-demographic factors, only carrots, fast food, fried snacks, and sweet snacks had no statistically significant association with agreeableness. All food types that had a significant association were positively associated with agreeableness and only soft drink (non-recommended food) was negatively associated. This meant respondents with higher agreeableness had a greater probability of not consuming soft drinks compared to those with lower agreeableness. The highest possibility was found in green leafy vegetables (OR = 1.041; CI = 1.018−1.064).

A negative association between agreeableness and soft drink consumption was found especially in adolescents (OR = 0.942; CI = 0.896−0.990) and in adults (OR = 0.977; CI = 0.957−0.997), but this association did not vary by sex. This negative association was also found in the consumption of fried snacks in males (OR = 0.976; CI = 0.954−0.999) and in adults (OR = 0.981; CI = 0.964−0.997), and sweet snacks in adults (OR = 0.981; CI = 0.966−0.997). In addition, agreeableness was associated in adults for green leafy vegetables (OR = 1.028; CI = 1.003−1.054), banana (OR = 1.027; CI = 1.011−1.044), papaya (OR = 1.024; CI = 1.006−1.043), and mango (OR = 1.018; CI = 1.001−1.035).

Supplementary Table 6 shows that after controlling for socio-demographic factors, only sweet potatoes, banana, papaya, mango, and fast food had no statistically significant association with neuroticism. Four non-recommended foods: instant noodle, soft drink, fried snacks, and sweet snacks were positively associated with neuroticism, while four recommended foods: meat, dairy, green leafy vegetables, and carrot were negatively associated. Fried snacks have the highest OR (OR = 1.021; CI = 1.009−1.033) and the lowest was green leafy vegetables (OR = 0.942; CI = 0.925−0.958). This meant that respondents with higher neuroticism increased their consumption of fried snacks by 1.021 times and decreased their consumption of green leafy vegetables by 0.942 times compared to those with lower neuroticism. Only meat and sweet snacks where all control variables had a significant correlation with the association between neuroticism and eating habits according to the food type.

Neuroticism was also associated in adults with all those four recommended foods (negative association) and four non-recommended foods (positive association)

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with the same association. The association between neuroticism and sweet snacks was stronger in the elderly (OR = 1.081; CI = 1.025−1.140) than in adults (OR = 1.016; CI = 1.004−1.029), but no association was found in adolescents. Additionally, neuroticism was also associated with soft drinks (OR = 1.024; CI = 1.001−1.047) and sweet snacks (OR = 1.018; CI = 1.001−1.034) in females, and fried snacks in males (OR = 1.029; CI = 1.011−1.048). The relationship between neuroticism with dairy, green leafy vegetables, and instant noodles did not vary by sex.

Table 3 shows that after controlling for socio-demographic factors, only agreeableness had no statistically significant association with physical activity. Openness (p = 0.010) and conscientiousness ($p < 0.001$) were positively associated with physical activity. Respondents with higher conscientiousness had a 1.045 times higher probability of engaging in more intense physical activity than those with lower conscientiousness, while openness had a lower probability of 1.015 times. In addition, all gender, marital status, education, and occupation were correlated with this association.

The relationship between physical activity and agreeableness did not vary by sex or age group. Meanwhile, physical activity was found to be associated with conscientiousness in adolescents (OR = 1.059; CI = 1.016−1.103) and adults (OR = 1.042; CI = 1.026−1.058), but not in the elderly. This association did not vary by sex. In addition, openness was associated with physical activity only in females (OR = 1.018; CI = 1.002-1.034) and the elderly (OR = 1.065; CI = 1.017-1.115).

Table 4 shows that there was still a statistically significant association between conscientiousness (p = 0.002), extraversion ($p < 0.001$), and neuroticism ($p < 0.001$) with obesity even after controlling for socio-demographic factors. Extraversion and conscientiousness were positively associated with obesity, which meant respondents with higher extraversion were 1.079 times more likely and conscientiousness was 1.025 times more likely to be obese compared to respondents with lower scores. Meanwhile, neuroticism had a negative association or protective effect on obesity (OR = 0.966; CI = 0.953−0.978). In addition, all gender, marital status, age, education, and occupation (except self-employed) were correlated with this association.

Conscientiousness was associated with obesity only in females (OR = 1.031; CI = 1.010−1.051) and in adults (OR = 1.027; CI = 1.010−1.044). Neuroticism was associated with obesity only in males (OR = 0.935; CI = 0.916−0.955) and in adults (OR = 0.957; CI = 0.944−0.970). Meanwhile, extraversion was associated with obesity in adolescents (OR = 1.069; CI = 1.012−1.128) and in adults (OR = 1.078; CI = 1.064−1.092), but not in the elderly. The association between obesity and extraversion also appeared to be stronger in females (OR = 1.083; CI = 1.066−1.101) than in males (OR = 1.074; CI = 1.053−1.096). This showed that women who have higher extraversion were more likely to be overweight or obese.

TABLE 3 Multivariate analysis between Big Five Personality Traits with physical activity and control variables.

Variables	Physical Activity			
	P-Value	OR	95% CI	
			Lower	Upper
Openness	0.010	1.015*	1.004	1.027
Age	0.075	1.002	1.000	1.004
Gender				
Male	<0.001	1.218*	1.159	1.280
Female (referent)				
Marital status				
Married/living together	<0.001	1.325*	1.236	1.420
Divorced/separated	0.023	1.148*	1.019	1.292
Never married (referent)				
Education				
Not attending school	<0.001	1.273*	1.122	1.445
Attending school (referent)				
Occupation				
Unemployed	<0.001	0.702*	0.662	0.743
Self-employed	<0.001	1.182*	1.116	1.251
Worker (referent)				
Conscientiousness	<0.001	1.045*	1.030	1.059
Age	0.186	1.001	0.999	1.003
Gender				
Male	<0.001	1.221*	1.162	1.283
Female (referent)				
Marital status				
Married/living together	<0.001	1.298*	1.210	1.391
Divorced/separated	0.045	1.129*	1.003	1.271
Never married (referent)				
Education				
Not attending school	<0.001	1.278*	1.127	1.450
Attending school (referent)				
Occupation				
Unemployed	<0.001	0.710*	0.670	0.752
Self-employed	<0.001	1.186*	1.121	1.256
Worker (referent)				
Agreeableness	0.286	1.008	0.993	1.023
Age	0.123	1.002	1.000	1.004
Gender				
Male	<0.001	1.223*	1.164	1.285
Female (referent)				
Marital status				
Married/living together	<0.001	1.321*	1.232	1.415
Divorced/separated	0.029	1.141*	1.013	1.284
Never married (referent)				
Education				
Not attending school	<0.001	1.261*	1.112	1.431
Attending school (referent)				
Occupation				
Unemployed	<0.001	0.700*	0.661	0.742
Self-employed	<0.001	1.183*	1.117	1.252
Worker (referent)				

*Significant at $p < 0.05$ using binary logistic regression test.

TABLE 4 Multivariate analysis between Big Five Personality Traits with obesity and control variables.

Variables	Obesity			
	P-Value	OR	95% CI	
			Lower	Upper
Conscientiousness	0.002	1.025*	1.009	1.041
Age	<0.001	1.011*	1.009	1.013
Gender				
Male	<0.001	0.429*	0.406	0.453
Female (referent)				
Marital status				
Married/living together	<0.001	2.500*	2.291	2.729
Divorced/separated	<0.001	1.593*	1.392	1.824
Never married (referent)				
Education				
Not attending school	<0.001	0.461*	0.400	0.532
Attending school (referent)				
Occupation				
Unemployed	0.004	0.911*	0.854	0.971
Self-employed	0.272	1.035	0.974	1.099
Worker (referent)				
Extraversion	<0.001	1.079*	1.065	1.092
Age	<0.001	1.012*	1.010	1.014
Gender				
Male	<0.001	0.444*	0.420	0.469
Female (referent)				
Marital status				
Married/living together	<0.001	2.546*	2.333	2.779
Divorced/separated	<0.001	1.637*	1.429	1.875
Never married (referent)				
Education				
Not attending school	<0.001	0.480*	0.416	0.553
Attending school (referent)				
Occupation				
Unemployed	0.008	0.916*	0.859	0.977
Self-employed	0.468	1.023	0.962	1.087
Worker (referent)				
Neuroticism	<0.001	0.966*	0.953	0.978
Age	<0.001	1.011*	1.009	1.013
Gender				
Male	<0.001	0.421*	0.398	0.445
Female (referent)				
Marital status				
Married/living together	<0.001	2.519*	2.308	2.748
Divorced/separated	<0.001	1.601*	1.398	1.833
Never married (referent)				
Education				
Not attending school	<0.001	0.459*	0.399	0.529
Attending school (referent)				
Occupation				
Unemployed	0.004	0.910*	0.853	0.970
Self-employed	0.302	1.033	0.972	1.097
Worker (referent)				

*Significant at $p < 0.05$ using binary logistic regression test.

Discussion

Big five personality traits and eating habits

Eating habits were found related to personality, so personality was assessed as contributing to certain eating patterns (Mõttus et al., 2013; Sutin and Terracciano, 2015b). Based on data on the consumption of 17 types of food (including five types of non-recommended foods: instant noodles, fast food, soft drink, fried snacks, and sweet snacks) and personality based on the Big Five Personality Traits, also after controlling for socio-demographic factors (age, gender, education, occupation, and marital status), the following results were obtained. This study showed that rice was not associated with all dimensions of personality, which could be because the staple food of the Indonesians is rice and very few people do not eat it.

This study found openness was positively associated (especially in adults), both with recommended and non-recommended foods, which was positively associated with eating all food types tested, and the most likely positive association was with green leafy vegetables and the lowest was with fried snacks only a slight difference. This may indicate the nature of openness to accepting various types of food, both healthy and unhealthy. This study also found a positive association between openness and fried snacks in men. This might be because men tended to have higher openness scores than women (Magee and Heaven, 2011; Armon et al., 2013; Intiful et al., 2019).

In previous studies, openness was associated with a Mediterranean-style diet and avoidance of sweet-based forms of diet (Mõttus et al., 2013), moreover, openness was found to be the most consistent and strongest result when associated with eating healthy foods (Mõttus et al., 2013; Tiainen et al., 2013). Openness was positively associated with eating plant-based food and fish (Pfeiler and Egloff, 2020), fruits and vegetables (Tiainen et al., 2013; Keller and Siegrist, 2015; Conner et al., 2017), and was negatively associated with eating meat (Keller and Siegrist, 2015; Pfeiler and Egloff, 2020), sugary drinks (Keller and Siegrist, 2015), and potato chips (Conner et al., 2017), however, other studies showed that openness was associated with increased consumption of wine (Gustavsen and Rickertsen, 2019) and non-recommended products (Gacek et al., 2021). The different results can be explained by the characteristics of openness that are more open to new experiences, as well as greater curiosity and exploration, making them more open to change so that they are more open to habits that are considered sustainable, for example, it is easier to adopt new adaptive eating patterns and overcome taste aversions (Mõttus et al., 2013; Conner et al., 2017), including consuming healthier foods such as fruits and vegetables, but if healthy eating habit has been habituated or perceived to be more familiar, it may no longer match the characteristics of higher openness

(Mõttus et al., 2013). The different results were also possible due to the variation in the characteristics of the studied sample which may lead to different behavioral tendencies considering that openness may adopt healthy or unhealthy eating behaviors.

This study found that conscientiousness was positively associated with eating recommended foods (especially in adults and except mango, which was not associated), with the highest probability of consuming green leafy vegetables (did not vary by sex or age group). Conscientiousness was not associated with all non-recommended foods: fast food, soft drink, instant noodle, fried snacks, and sweet snacks. This study also found a negative association between conscientiousness and meat in adolescents and soft drinks in women and a positive association between dairy and fast food in men.

Consistent with the previous studies, conscientiousness tends to choose healthy foods and foods recommended in dietary guidelines (Keller and Siegrist, 2015), as in the study by Mõttus et al. (2013) higher conscientiousness was associated with a tendency to have a healthier diet. In the study by Gacek et al. (2021), there was an increase in eating most recommended products and a decrease in eating most non-recommended products, and in the study by Ibigbami (2012), conscientiousness was found to be negatively associated with alcohol consumption, which was similar to previous studies, where it seemed that conscientiousness had a holistic effect not only on alcohol use but on all aspects of their wellbeing. Conscientiousness was also found to be positively associated with eating plant-based food and fish (Pfeiler and Egloff, 2020), fruits (Keller and Siegrist, 2015), and the combined daily consumption of vegetables and fruits compared to lower conscientiousness (Conner et al., 2017). Conscientiousness was negatively associated with eating meat (Keller and Siegrist, 2015; Pfeiler and Egloff, 2020), sugary drinks, sweet and savory foods (Keller and Siegrist, 2015), and foods containing preservatives (among young women) (Jaworski and Rozenek, 2016). Additionally, increasing conscientiousness also reduces the expected frequency of beer consumption (Gustavsen and Rickertsen, 2019). Meanwhile, lower conscientiousness tends to perceive their eating habits as more unhealthy and have poor eating habits (Lawler, 2018). This is due to conscientiousness tends to be more careful in choosing the food consumed (Keller and Siegrist, 2015; Nelvi, 2016). Furthermore, it is also due to the level of discipline and orderliness that affects adherence to healthy diets (such as Mediterranean diet) and avoidance of unhealthy foods (such as sweet foods) (Mõttus et al., 2013).

In this study, extraversion was positively associated with eating all types of food tested (except fish, which was not associated), which meant a positive association with eating both recommended and non-recommended foods (especially higher in women than men), with the highest probability of consuming fast food. This can be supported by previous studies, women scored higher on extraversion than men (Magee and Heaven, 2011; Armon et al., 2013; Purnamawati and Yuliati, 2016).

Previous studies showed that extraversion was negatively associated with eating carbohydrate-based food (Pfeiler and Egloff, 2020) and was positively associated with eating meat (Keller and Siegrist, 2015; Pfeiler and Egloff, 2020), plant-based food, and fish (Pfeiler and Egloff, 2020), fruits and vegetables (Purnamawati and Yuliati, 2016; Conner et al., 2017), whole-grain bread (Jaworski and Rozenek, 2016), sugary drinks, sweet and savory foods (Keller and Siegrist, 2015), alcohol (Ibigbami, 2012; Kye and Park, 2012), wine (Gustavsen and Rickertsen, 2019), and Mediterranean diet (Mõttus et al., 2013). Other studies on young women also found that individuals with higher extraversion tend to choose foods that are considered to have a good impact on health (Jaworski and Rozenek, 2016). Based on those results, it can be seen that extraversion tends to increase consumption of both recommended and non-recommended foods. This was also seen in the study by Gacek et al. (2021) who suggested that more extroverted individuals tend to be more assertive, optimistic, open, sensation-seeking, and happy to socialize may increase consumption of most recommended products, but consumption of non-recommended products decreased with red meat and lard, while increased with sweets and alcohol. This may be due to extraversion who prefer to socialize and is more attached to social networks (Friedman et al., 2010) so they need energy from gathering with other people. Therefore, they regularly attend social situations and eat more often with other people, but the food selection is limited to the menu provided (Tiainen et al., 2013) so it is possible to frequently consume non-recommended foods which can have a negative impact on health (Keller and Siegrist, 2015). In this study, perhaps the biggest tendency was meeting other people in restaurants selling fast food, as this study found that the highest probability was fast food consumption.

In this study, agreeableness was positively associated with eating several recommended foods: fish, fruits (banana, papaya, mango, especially in adults), and most likely green leafy vegetables (especially in adults), and negatively associated with eating non-recommended foods: soft drink (especially in adolescents and adults), fried snacks in men and adults, and sweet snacks in adults. The rest of the food types were unrelated. The results of this study were in line with previous studies, higher agreeableness was associated with a healthier diet (Mõttus et al., 2013). In previous studies, agreeableness was found to be positively associated with eating plant-based food and fish (Pfeiler and Egloff, 2020) and fruit (in women) (Tiainen et al., 2013). Agreeableness was negatively associated with eating carbohydrate-based food (Pfeiler and Egloff, 2020), meat (Keller and Siegrist, 2015), and frequency of wine and beer consumption (Gustavsen and Rickertsen, 2019). However, other studies showed that the association between agreeableness and eating habits appears to be rather weak and inconsistent across studies (Pfeiler and Egloff, 2020).

Such agreeableness was found to be associated with increased consumption of non-recommended products (Gacek et al., 2021), and infrequent avoidance of salty foods (among young women) (Jaworski and Rozenek, 2016), and poor or unhealthy diet patterns (Kye and Park, 2012). It may be that agreeableness consumes less meat because ethical concerns based on high altruism and sympathy also apply to animals (Keller and Siegrist, 2015), or agreeableness was significantly negatively associated with alcohol consumption because individuals with high agreeableness are quite sociable and naturally have good and respectful natures, so they are easy to adopt other forms of coping strategies that could reduce the tendency to use or abuse alcohol (Ibigbami, 2012), or other traits such as obedience make them more likely to adhere to rules such as dietary guidelines, but other traits that tend to be easy to trust and have a high tolerance of others, happy to help, kind and gentle, make them easily influenced by their social environment which may force them to follow unhealthy dietary practices (Rahmadian, 2011; Kye and Park, 2012). These might contradict and confuse them, but as adults, they might begin to realize the benefits of dietary guidelines, therefore in this study the healthy eating habit was found particularly in higher agreeableness adults.

This study found that neuroticism was positively associated with eating almost all non-recommended foods (especially in adults): instant noodles, soft drinks, sweet snacks, and the highest probability was eating fried snacks (fast food was unrelated). Neuroticism was also positively associated with soft drinks and sweet snacks in women and fried snacks in men. In addition, neuroticism was negatively associated with eating several recommended foods (especially in adults): meat, dairy, carrot, and the highest probability of green leafy vegetable consumption, the rest of the food types were unrelated.

Consistent with this finding, neuroticism was found to be associated with poorer diet quality (Tiainen et al., 2013). In previous studies, neuroticism was positively associated with eating carbohydrate-based food and meat (Pfeiler and Egloff, 2020), sweet and savory foods (Keller and Siegrist, 2015), soft drinks (for women) (Tiainen et al., 2013), French fries (for men) (Conner et al., 2017), and non-recommended products (including sweets) (Gacek et al., 2021). Neuroticism was negatively associated with plant-based food and fish (Pfeiler and Egloff, 2020), vegetables (in women) (Tiainen et al., 2013), recommended whole grain cereals (Gacek et al., 2021), and the Mediterranean diet (Mõttus et al., 2013) which dietary recommendations encourage eating healthy foods. This can happen because individuals with high neuroticism have low self-esteem, high sensitivity, and are emotionally unstable (Gacek et al., 2021), which causes their mood to fluctuate often, also easily feel upset and disturbed, which is then overcome by eating because they react to eating behavior as a form of reassurance over negative emotions (Elfhag and Morey, 2008; Nelvi, 2016), thereby ignoring healthy food choices. It can be worse, especially in productive age or adulthood, where stress levels are higher and they are more prone to depression. Meanwhile, individuals with emotional stability (low levels of neuroticism) tend to choose foods considered to have a good impact on health (Jaworski and Rozenek, 2016).

Big five personality traits and physical activity

In this study, only openness, conscientiousness, and agreeableness were associated with physical activity. However, after controlling for age, gender, education, occupation, and marital status, only openness and conscientiousness remained associated with physical activity, but age did not seem to moderate this association. Meanwhile, the association between agreeableness and physical activity was weakened by these socio-demographic factors so that it no longer had a statistically significant association.

This study found that extraversion was not associated and conscientiousness was positively associated with physical activity. Slight differences were found in previous findings that high extraversion and conscientiousness (as well as low neuroticism) were found to be associated with higher or more active levels of physical activity (Rhodes, 2006; Rhodes and Smith, 2006; Allen and Laborde, 2014; Stephan et al., 2014b; Mõttus et al., 2016). Individuals with higher extraversion and conscientiousness tend to have more energy (Terracciano et al., 2013) and an active nature is theorized as a key aspect of extraversion and conscientiousness that represents their tendency to be busy and energetic (Rhodes, 2006). Thus, physical activity can be used as an activity in accordance with the energy capacity they need (Stephan et al., 2014b). Individuals with low extraversion may be less likely to engage in physical activity because they find it less enjoyable and have a lower level of control over it than people with higher extraversion (Rhodes, 2006). Meanwhile, individuals who lack order and self-discipline (low conscientiousness) are likely to have more difficulty maintaining their physical activity plans (Rhodes, 2006). Extraversion and conscientiousness also largely have a positive association with activity variability within individuals (Mõttus et al., 2016). The difference in results on extraversion found in this study may be due to the fact that Indonesians have very low levels of physical activity compared to other countries (Althoff et al., 2017), so although individuals with high extraversion have more energy and like to gather with other people, this is directed toward activities other than physical activity and their social environment also do not support physical activity due to the sedentary habits of the community. Therefore, extraversion was not associated with physical activity in this study.

This study also found that individuals with higher conscientiousness in adolescents and adults tended to be more active, but there was no association in the elderly. This might be because age was positively correlated with a decreased physical activity where children were more active than adults (Miles, 2007) and physical activity steadily decreased in the later stages of life (Wilson and Dishman, 2015). However, age was also related to personality such as conscientiousness which tended to increase with age (Brummett et al., 2006). These perhaps became very contradictory in old age, thus negating the relationship between conscientiousness and physical activity in the elderly.

This study found that openness was positively associated with physical activity (especially in women and the elderly), which was consistent with previous findings. Stephan et al. (2014a) showed that not only extraversion, but openness was also associated with the possibility of being involved in various physical, cognitive, and social activities, and also found a consistent pattern in two different Western societies (United States and France), that there were intrinsic tendencies toward extraversion and openness to having a more active lifestyle. These characteristics are perhaps more dominant in women and older people, as they tend to prefer to gather, talk, and do activities together, including physical activities. Openness characteristics which have a tendency to new ideas and experiences and also prefer variety are characteristics of individuals who are open and can lead to active involvement in various types of activities (Stephan et al., 2014a) thus enabling individuals to have a higher level of physical activity because physical activity can encourage a tendency to explore and seek new and varied experiences (Stephan et al., 2014b).

In this study, agreeableness was found to be unrelated to physical activity. This result was consistent with other studies that also found no association between agreeableness and physical activity, perhaps suggesting that the tendency to trust and help others is unrelated to motivation and involvement in physical activity (Courneya and Hellsten, 1998; Sutin et al., 2016; Intiful et al., 2019). However, in the study by Stephan et al. (2014a), agreeableness showed a positive association with variations in the type of activity in one of the samples tested. Physical activity also encourages a tendency to be exposed to various bodily, emotional, and social experiences which can also produce social interactions that may contribute to the maintenance of a prosaic orientation that characterizes agreeableness (Stephan et al., 2014b).

In this study, neuroticism was unrelated to physical activity, but in previous studies, neuroticism was negatively associated with physical activity in one of the samples tested in the studies by Stephan et al. (2014a,b). Overall, neuroticism seems to be negatively associated with physical activity but has little impact (Rhodes and Smith, 2006). Theoretically, neuroticism with a tendency to feel insecure and jealous may look to others for motivation to behave (Rhodes, 2006) for example in physical activity. Feelings of worry about appearance, feelings of obligation, and feelings of guilt if they do not exercise become central to their motivation for physical activity (Ingledew and Markland, 2008), but due to their low self-control which is reflected by impulsivity (Elfhag and Morey, 2008), it is difficult for them to maintain the intention and schedule in exercising. This may have a contradictory impact on neuroticism and therefore neuroticism was unrelated to physical activity.

The results of this study were slightly different from previous studies. This may be due to variations and differences in the characteristics of the respondents studied since a study related to the association between Big Five Personality Traits and physical activity has never been studied before in Indonesians.

Big five personality traits and obesity

In this study, both before and after being controlled by socio-demographic factors, conscientiousness, extraversion, and neuroticism were associated with obesity, it seemed that all control variables moderated this association except working as self-employed. Meanwhile, openness and agreeableness were not associated with obesity.

The positive association between conscientiousness and obesity (especially in women and adults) found in this study was not unexpected. Compared to other dimensions, low conscientiousness and high neuroticism had the strongest associations with BMI and obesity (Sutin and Terracciano, 2015b). But based on a meta-analysis by Jokela et al. (2013), only conscientiousness was consistently associated with obesity. Inconsistent results were found for other dimensions in previous studies. Previous studies showed that conscientiousness was negatively associated with nutritional status, which meant that low conscientiousness was associated with higher nutritional status (obesity) in adult samples (Magee and Heaven, 2011; Sutin et al., 2011; Sutin and Terracciano, 2015b; Pfeiler and Egloff, 2020) and older people (Mõttus et al., 2013). Conscientiousness was also found to be negatively associated with several measures of body weight (Armon et al., 2013). Conscientiousness was associated with healthier body weight, possibly because high conscientiousness was characterized as conscientious, efficient, orderly, obedient, organized, and disciplined individuals, so they were more likely to have behaviors that support a healthy weight or maintain the desired body shape, such as eating habits, following a meal plan, eating at the same time every day, and exercising (Brummett et al., 2006; Terracciano et al., 2009; Sutin et al., 2011; Sutin and Terracciano, 2015b). Meanwhile, low conscientiousness had difficulties in self-control, so they tend to overeat, lack physical activity, and had poor eating habits such as chaotic eating schedules, which can then lead to obesity (Magee and Heaven, 2011; Sutin and Terracciano, 2015b). Although conscientiousness was associated with healthier eating habits and more physically active found in this study, the different results in association with nutritional status may be due to other mechanisms linking this association. For example, an imbalance in total energy intake and energy expenditure that was not investigated in this study or other possibilities due to physiological factors such as health conditions or history of disease. Moreover, several previous studies found an association between personality dimensions and several physiological and genetic mechanisms that can then affect body composition (Kakizaki et al., 2008), such as the finding of low conscientiousness associated with higher circulating levels of leptin (Sutin et al., 2013) and FTO genetic variant had little effect on the relationship between personality traits with underweight and overweight (Terracciano et al., 2009). Therefore, future studies may further investigate other mechanisms that might underlie this association.

This study found that neuroticism was negatively associated with obesity (especially in men and adults). However, previous studies found inconsistent findings such as a negative association between neuroticism and nutritional status (Kakizaki et al., 2008) as well as a positive association (Sutin et al., 2011; Pfeiler and Egloff, 2020). Individuals with low conscientiousness or high neuroticism were prone to obesity (Sutin et al., 2011). High neuroticism was characterized by individuals who tend to have emotional vulnerability, fear, anxiety, and depression related to eating behavior for comfort due to negative emotions, poor eating habits, avoidance of physical activity, and impulsiveness associated with emotional eating can lead to obesity (Elfhag and Morey, 2008; Magee and Heaven, 2011). This can be seen in low self-discipline (conscientiousness) and impulsiveness (neuroticism) which reflect poor individual self-control (Elfhag and Morey, 2008). Moreover, this impulsivity trait was the strongest predictor of nutritional status which was found in many studies (Terracciano et al., 2009). However, Terracciano et al. (2009) found that lean people scored higher on neuroticism, but scored lower on impulsivity. The inconsistent results on neuroticism and obesity might be explained by the nature of their susceptibility to depression, especially in productive age or adulthood. Depression can trigger individuals to eat more or less, so it was strongly associated with emotion and nutritional status (Yilmaz and Köse, 2020). This can lead individuals to have a more or less nutritional status. As in this study, although neuroticism was found to be positively associated with eating non-recommended foods and negatively associated with eating recommended foods, but neuroticism was negatively associated with obesity, this might be related to their susceptibility to depression so that it affected the nutritional status that tended to be not obese.

In this study, extraversion was positively associated with obesity (especially in adolescents, adults, and higher in women). This finding was consistent with other studies that found a positive association between extraversion and nutritional status (Magee and Heaven, 2011; Sutin et al., 2011), but another study found that extraversion was negatively associated with BMI among women but not among men (Sutin and Terracciano, 2015b). Brummett et al. (2006) showed that men with higher extraversion had a higher BMI explained by extraversion traits that are adventurous, fun-seeking, sociable, and gregarious, which may lead them to consume more high-calorie foods and/or consume more alcohol. Armon et al. (2013) offered an alternative explanation that the tendency of individuals with high positive moods to be more careless, feel less vulnerable to unwanted health conditions, and adopt unhealthy behaviors that lead to overweight. Although in this study extraversion was associated with eating recommended and non-recommended foods (especially higher in women), which reflected their lack of attention to the food they consumed, which then may have an impact on obesity, in another study, extraversion was associated with greater physical activity (Hoyt et al., 2009), which means they actually have the potential to be able to maintain a healthy weight.

Our findings could be supported by findings from previous studies that obesity affects British and Indonesian women more than men (Mihardja and Soetrisno, 2012), and women tended to consume more sweet foods such as candy and chocolate (Conner et al., 2017). Another study also found that men had higher quality food intake and eating habits than women (Puspadewi, 2014), but other studies found the opposite (Mõttus et al., 2013). In addition, the increase in BMI occurs mainly in young and middle adults, then after passing the age of 60 years, body weight decreases rapidly and returns to a value comparable to that of young adults (Sutin et al., 2011; Suiraoka, 2012; Chaudhuri and Bandopadhyay, 2014).

This study found no association between obesity with openness and agreeableness. Previous studies showed inconsistent findings, which suggested that nutritional status was unrelated to agreeableness (Pfeiler and Egloff, 2020) and openness (Sutin and Terracciano, 2015a; Pfeiler and Egloff, 2020), positively associated with openness (Sutin et al., 2011), also negatively (Sutin et al., 2011; Sutin and Terracciano, 2015a) and positively associated with agreeableness (Magee and Heaven, 2011). Openness was characterized by an open and curios nature may be easier to adopt a new adaptive eating pattern, but perhaps if the eating habit has been habituated or perceived to be more familiar, it may no longer match the characteristics of higher openness (Mõttus et al., 2013). Meanwhile, agreeableness was characterized by individuals who are warm, empathetic and need the consideration of others, which may lead to contradictory eating behaviors that can then affect body weight (Armon et al., 2013). This may be what causes the different findings in various studies or even the lack of association between nutritional status with openness and agreeableness.

Differences in results with previous studies may be due to variations in the sample tested and methodological differences such as the composition of the Big Five Personality Trait questions used differently from previous studies. Due to inconsistent findings across many studies, it is difficult to draw conclusions. Thus, further study is needed to describe a more specific mechanism regarding the association between personality and nutritional status.

What can we learn?

In this study, openness was found to be positively associated with both recommended and non-recommended foods (especially in adults), positively associated with physical activity (especially in women and the elderly), but not associated with obesity. This can be explained by the fact that even though they were more active, the nature of individuals with high openness tend to like variety and be open to new experiences and ideas, which allows them to more easily follow new healthy or unhealthy dietary guidelines, which leads to openness did not determine nutritional status. Therefore, individuals with high openness should be directed to adaptive behavior patterns that come with a lot of variety so that they can meet their needs for variety and their interest in new experiences, such as food menus or healthy types of diets that regularly changed various physical activities. Meanwhile, low openness maybe enjoys a more fixed schedule, not too varied, and a selection of menus and activities that are more familiar to them due to their more conservative and conventional tendencies.

Conscientiousness was positively associated with eating almost all recommended foods (especially in adults) and not associated with all non-recommended foods in this study. Moreover, conscientiousness was positively associated with physical activity (especially in adolescents and adults), but also positively associated with obesity (especially in women and adults), which was an unexpected result. This may be because in this study conscientiousness was not associated with eating non-recommended foods, so they could have high or low levels of consumption, although conscientiousness increased the possibility of consuming recommended foods and physical activity, which then impacted obesity, or there may be another mechanism underlying this relationship (such as their knowledge of healthy foods which was not examined in this study). Therefore, individuals with high conscientiousness can be directed to adaptive behavior with clear and organized guidelines and schedules so that it will be easier to adopt because it is in line with their conscientious, disciplined, organized, and obedient nature. Meanwhile, low conscientiousness may need behavioral strategies, implementation intentions, and behavior change goals such as increasing physical activity (Rhodes, 2006).

This study found that extraversion was positively associated with eating recommended and non-recommended foods (especially higher in women), was not associated with physical activity and was positively associated with obesity (especially in adolescents, adults, and higher in women). This was possible because food choices are disregarded by individuals with high extraversion due to their tendency to like to gather and even eat with other people more often, which may limit their food choices (Tiainen et al., 2013), in addition to being more careless and inattentive their attention to unwanted health conditions (Armon et al., 2013) which then has an impact on obesity. Therefore, individuals with high extraversion may be more suited to group activities and activities that require a lot of energy as it suits their sociable and energetic nature to make it easier for them to adopt adaptive behavior. Meanwhile, low extraversion may be able to take advantage of behavior change strategies that do not require much energy and do not involve many people, such as exercising at home.

Agreeableness was positively associated with eating several recommended foods and negatively associated with eating non-recommended foods (especially in adults). However, agreeableness was unrelated to physical activity and obesity. This may be because the nature of individuals with high agreeableness who like to help and easily trust others has no effect on their motivation and involvement in physical activities (Courneya and Hellsten, 1998; Sutin et al., 2016; Intiful et al., 2019). In addition, their tendency to obey and trust others leads them to be easily influenced by their social environment which can lead them to adopt healthy or unhealthy dietary guidelines depending on the individual who directs them or individuals they trust, causing contradictory eating behaviors and agreeableness did not determine nutritional status. Therefore, individuals with high agreeableness can be directed to adaptive behavior by involving the people around them, especially those they trust, so that they can adopt the behavior more easily. Meanwhile, low agreeableness may benefit from behavior change strategies related to independence and avoid the involvement of others, as they tend to be suspicious and critical of others, such as preparing their own healthy meals.

This study found that neuroticism was positively associated with eating four of the five non-recommended foods and negatively associated with four recommended foods (especially in adults), and the rest was unrelated. Moreover, neuroticism was found to be unrelated to physical activity and negatively associated with obesity (especially in men and adults). This may be because individuals with high neuroticism tend to be unstable, emotional, and impulsive, which indicates their low self-control, so they find it harder to maintain the intention to do physical activity, but in addition, they may engage in physical activity because they feel insecure or see others as motivation to exercise (Rhodes, 2006), so neuroticism was unrelated to physical activity in this study. Additionally, individuals with high neuroticism susceptibility to stress may cause them to tend to have low intakes in this study which might protect them from obesity even though they had poor quality food choices. However, if poor eating habits are taken frequently and continuously, it will have a negative impact on their nutritional and health status. Therefore, individuals with higher neuroticism may be able to involve friends or family with lower neuroticism in making behavioral changes, such as exercising regularly (Rhodes, 2006), and can benefit from menu planning and regular meal times.

Strengths and limitations

The strengths of this study included a large study with over 30,000 respondents so that the results can be more representative of the study population. Our statistical analysis also included control variables to obtain the independent effect of personality on nutrition-related variables. In addition, since evidence related to the association between personality traits, eating habits, physical activity, and nutritional status was scarcely found in peer-reviewed articles in the Indonesian setting, this study is, therefore, a relatively new and pioneering study linking personality and nutrition in an Indonesian setting. Limitations included limited data quality control and the availability of personality and nutrition-related variables, as we used secondary data. Not all samples were used in this study due to data completeness, but among the excluded respondents, there was no indication that they had a BMI that tended to be higher or lower, so there was no systematic bias. The physical activity duration data processing also used an approach method because IFLS5 had only time frame data, which might lead to overestimation or underestimation. Another limitation, measuring obesity using BMI has a weakness because it is unable to distinguish between body fat and fat-free mass (Johansson et al., 2009). The absence of body composition in assessing obesity leads to a risk of bias, therefore more precise measurements of obesity are recommended, such as fat mass and waist circumference (Johansson et al., 2009). Lastly, this study was a cross-sectional study, so it was not possible to draw conclusions about causality.

Conclusion

After controlling for socio-demographic variables, openness was positively associated with recommended and non-recommended foods, and physical activity, and not associated with obesity. Conscientiousness was positively associated with almost all recommended food types, physical activity, and obesity, and not associated with all non-recommended foods. Extraversion was positively associated with recommended and non-recommended foods and obesity, and not associated with physical activity. Agreeableness was positively associated with several recommended foods, negatively associated with one non-recommended food, and not associated with physical activity and obesity. Neuroticism was positively associated with almost all non-recommended foods, negatively associated with four recommended foods and obesity, was also not associated with physical activity. Behavior change can take into account individual characteristics such as personalized strategies with personality because the adaptation of personality characteristics can be modified even though the personality tends to be persistent. This strategy can be used to improve nutritional status or public health because personality, particularly conscientiousness, was found to be consistent with previous studies across western and eastern countries that conscientiousness had a relationship with eating habits and physical activity. Additionally, higher extraversion (especially in women) was found to be more likely to be careless in food choices and more prone to obesity. Therefore, the understanding of personality needs to be improved so that health and nutrition improvement interventions are more effective and allow for sustainability as the interventions or programs are most suited to the needs of individual preferences. Programs to prevent obesity, improve physical activity, and healthy eating habits should be tailored to accommodate individuals with low conscientiousness personalities especially women with higher extraversion. This information can be useful not only to health professionals, but also to teachers, psychologists, and the community who target the promotion of healthy living or the prevention of nutrition and health problems.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS/ifls5.html

Author contributions

GP and TM conceived the project and research question. GP conducted the data analyses and wrote the original draft of the manuscript. TM and MR reviewed and edited the manuscript. TM was responsible for funding the publication of the manuscript. All authors contributed to data processing and read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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The sight of one's own body: Could qEEG help predict the treatment response in anorexia nervosa?

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Aims of the study: The study aims to identify the differences in brain activity between participants with anorexia nervosa and healthy control using visual stimulus conditions combined with the quantitative dense-array EEG recording analysis method called Brain Activation Sequences (BAS).

Materials and methods: 23 participants with anorexia nervosa and 21 healthy controls were presented with visual stimuli, including the subject's facial expressions and body images. The 128-channel EEG data were processed using BAS and displayed as activity in up to 66 brain regions. Subsequent cluster analysis was used to identify groups of participants exhibiting area-specific activation patterns.

Results: Cluster analysis identified three distinct groups: one including all healthy controls (HC) and two consisting of all participants with anorexia (AN-I with 19 participants and AN-II with four participants). The AN-I and AN-II groups differed in their response to treatment. Comparisons of HC vs. AN confirmed the dominance of the right cerebral hemisphere in participants with anorexia nervosa in two of the three reported conditions. The facial expressions condition, specifically the facial reaction expressing disgust, indicates the existence of a social attentional bias toward faces, whereas emotions remained undetected in participants. High limbic activity, medial frontal gyrus involvement, low fusiform cortex activity, and milder visual cortex activity in healthy controls compared to participants indicate that the facial expression stimulus is perceived by healthy subjects primarily as an emotion, not as the face itself. In the body image condition, participants showed higher activity in the fusiform gyrus and right insula, indicating activation of the brain's "fear network."

Conclusion: The study describes a specific pattern of brain activation in response to facial expression of disgust and body images that likely contributes to social-cognitive and behavioral impairments in anorexia. In addition, the substantial difference in the pattern of brain activation within the participants with AN and its association with treatment resistance deserves special attention because of its potential to develop a clinically useful prediction tool and identify potential targets for, for example, neuromodulatory treatments and/or individualized psychotherapy.

KEYWORDS

anorexia nervosa, qEEG, treatment response, facial expressions, perception, disgust

Introduction

Despite the increasing emphasis on prevention, treatment, and research in this area, the global impact of anorexia nervosa (AN) does not appear to have diminished in recent decades. While the overall incidence appears relatively stable, there has been an increase in the high-risk group (15–25 years; Smink et al., 2012), mortality remains one of the highest among psychiatric conditions (Roux et al., 2013), the disorder is evolving into a chronic condition in a significant group of participants, and treatment outcomes have lagged behind expectations, particularly in terms of long-term effect and impact on psychiatric symptoms vs. weight (Murray et al., 2019). A better understanding of the neurobiology of this disorder leading to new diagnostic and treatment response prediction tools is therefore pressing.

One of the prominent characteristics of AN is an abnormal perception and evaluation of body shape, which is manifested mainly by an overestimation of the patient's body size (Uher et al., 2005). Therapeutic approaches focus primarily on cognitive-behavioral therapy, supported by pharmacotherapy for common psychiatric comorbidities, especially anxiety and depression. According to current treatment models and strategies, the main goal is to achieve a change in emotional processing (Halls et al., 2021). However, the prevailing insight into the dynamics of these changes is deeply based on data obtained from measurements of body proportions, observation of patient behavior, and patient self-reports; methods for objective diagnosis and prediction of disease progression are still lacking (Seidel et al., 2018). This study attempts to address the problem described by Seidel regarding the current absence of methods to objectively diagnose and predict the development of AN by trying to answer the question of whether the brains of study participants produce patterns that distinguish between participants with AN and healthy controls when exposed to certain stimuli. The second question was whether there is a subgroup within the participants with AN with a specific response that reacts to the treatment differently or not at all.

One of the central irregularities described in AN is an increased sensitivity to punishment (Harrison et al., 2011). Research focusing on mindsets-shifting, central coherence, and decision-making disorders in participants with AN has shown that this is a stable feature even in recovered participants (Danner et al., 2012). In another experiment, participants with high levels of emotion dysregulation experienced an increase in AN symptomatology, whereas low levels of dysregulation predicted a decrease in symptom trajectory (Racine and Wildes, 2015). The authors of the revised cognitive-interpersonal model described AN-specific attention to detail and low willingness to change attitudes, which may have a heritable component. According to their findings, severely impaired global integration results in poor central coherence. Impaired social–emotional processing, manifested as attentional biases toward critical facial expressions and errors in interpreting and regulating emotions may be partly attributable to starvation.

A considerable body of work on AN has described the processing of visual stimuli, including various types of aversive images, such as emotional faces (Pollatos et al., 2008). Others have focused on the brain's response to shape/weight and neutral words (Blechert et al., 2011) as measured by event-related EEG potentials (ERPs) or functional imaging methods (Frank and Kaye, 2012; Wright et al., 2015). A widely cited study by Uher et al. (2005) suggests that the tendency to display diagnosis-specific AN symptoms (e.g., desire for thinness and fear of fatness) and behaviors (restriction, purging) is conceivable as preferential activation of specific neural pathways and circuits. However, according to a detailed review by Fuglset et al. (2016), many fMRI studies have focused on body and appearance, emotions, and other aspects of AN, including the identification of different brain regions involved in the processing of visual stimuli, with mixed results. For example, some studies have found a bias towards facial expressions (Harrison et al., 2010), others have found a bias away from faces (Fassino et al., 2004), while some have found no bias at all (Castro et al., 2010). All these studies focus on dynamic results in the form of ERPs with low spatial accuracy or fMRI experiments lacking temporal resolution. Neural visual stimulus processing in brain sub-networks can be of transient and fast nature. The fMRI might not have detected certain regions because of its ability to capture brain activation over more extended periods (Trautmann et al., 2009). Other brain areas involved in processing the stimulus, either emotional or cognitive, could stay invisible to the approach (Im, 2007).

We have applied two types of visual stimuli activating brain pathways to investigate differences in stimulus processing between participants and healthy controls using high-density nonlinear self-learning qEEG analysis. For the purpose of completeness, we would like to note that the evaluation of classical EEG is based on visual assessment of fit between the displayed signal and predefined patterns, whereas qEEG is based on mathematical signal processing and, strictly speaking, does not require visual assessment. The design of our study is based on the findings from experiments cited in the previous paragraphs, but seeks to minimize some of their technological limitations by combining high-density EEG and signal source localization. The experiment results were expected to confirm differences in gyrus usage between participants and controls, and to assess to what extend the group of participants with AN is homogenous.

The study design included tasks to confirm the validity of the obtained results. These included the repeatedly published dominance of the right hemisphere in AN; differences in stimulus processing between participants with AN and healthy controls in gyrus involvement supporting the existence of emotional and attentional biases in face processing and body image mismanagement in participants; specifically, in the facial expression of disgust, repeatedly pointed out by other researchers as eliciting a specific response (Kucharska-Pietura et al., 2004; Trautmann-Lengsfeld et al., 2013). The Brain Activation Sequences (BAS) method was chosen for its temporal resolution and ability to identify a sequential set of brain sites used in stimulus processing. The relevant section also presents a more conventional way of displaying the results.

Materials and methods

Study participants

Twenty-three female participants with a diagnosis of anorexia nervosa (AN), hospitalized in the Eating Disorder Treatment Unit (EDTU) at the Psychiatric Clinic of the 1st Faculty of Medicine, Charles University in Prague participated in the experiment. All participants met the criteria for the restrictive type of AN according to the DSM-5 (American Psychiatric Association. Dsm-5 Task Force, 2013), and all diagnoses were independently confirmed by two psychiatrists from the EDTU. The majority (82.6%) of participants were on medication including selective serotonin reuptake inhibitors, benzodiazepines, noradrenergic and specific serotonergic antidepressants, atypical antipsychotics, and serotonin antagonists and reuptake inhibitors. The control group consisted of 21 healthy volunteers, recruited mainly from female students, similar in age and education to the participants with AN. All students who formed the healthy control group expressed interest in joining the experiment during the lectures in which the design of the experiment was presented. They were not financially rewarded for their participation, but motivated by their interest in the subject. All healthy controls passed the Eating Disorder Examination Questionnaire (EDE-Q) screening (Aardoom et al., 2012) and psychiatric examination for all forms of eating disorders with negative results. Descriptive statistics for both groups are shown in Table 1. Since the sample did not show a normal distribution, we present descriptive statistics in a format that allows a more detailed description of the population. None of the cases were the participants in the initial phase of treatment; all of them were past the halfway point in terms of planned hospitalization time. Status of participants with AN was continuously updated and during the experiment data processing phase, all these participants had completed their hospitalization so it was possible to evaluate the treatment outcome. Treatment outcome was rated by the attending psychiatrists on a scale of −2 to +2. Zero indicated no treatment effect, negative values deterioration, positive values improvement to significant improvement in the case of the outcome coded as +2.

Data acquisition

The basis of the project was the examination of data obtained from qEEG recordings, so we present the parameters associated with the technique and the chosen procedures. The recording was performed in a room designed for recording biological signals, shielded by a Faraday cage. A 128-channel EGI Net Amps 300 EEG amplifier, combined with a Geodesic Sensor Net, was used for recording, utilizing sponges moistened with a weak aqueous solution of potassium chloride for contact with the scalp. All participants were seated in a comfortable chair and fitted with a HydroCel Geodesic Sensor Net with 128 electrodes whose impedance was kept below 50 kΩ throughout the experiment to ensure maximum recording quality (Ferree et al., 2001). All channels used the reference electrode Cz for acquisition. A

TABLE 1 Descriptive statistics of study participants.

Category	Parameter	Min	Max	Median	Inter-quartile range	95% CIs	
						Lower bound	Upper bound
AN; *N* = 23	Age (years)	18	44	22	9	21.3	26.8
	Height (cm)	161	187	167	8	165.2	170.5
	Admission BMI	9.7	17.24	14	2.7	13	14.7
	Discharge BMI	12.6	18.7	16.1	2.6	15.7	17.1
HC; *N* = 21	Age (years)	18	35	23	5.5	22.4	26.4
	Height (cm)	159	185	172	12.5	168.6	175
	Examination BMI	18.69	24.8	20.8	1.39	20.4	21.7

BMI, Body Mass Index.

band-pass filter with cutoff frequencies set from 0.1 to 100 Hz with 3 dB attenuation, a gain of 1,000, and a sampling frequency of 500 Hz was used for recording, and a 16-bit A/D converter was used for digitizing the analog signal.

Stimulus presentation

Visual stimuli were presented to all participants in four blocks of 50 stimuli each. All pictures of a given set were displayed randomly on the screen, but the probability of displaying each picture was uniform and the display time was set to 1 s to cover the potentials associated with emotion and cognitive stimulus processing (Trautmann-Lengsfeld et al., 2013). In addition, participants were provided with a keypad in their dominant hand to express their feelings about the stimulus, in other words, whether they liked or disliked the presented image. Although manual controls during EEG recording increase the risk of motion artifacts, we wanted the presence of buttons to ensure that the participant was paying maximum attention to the stimuli. In addition, the presentation screen was equipped with a camera synchronized with the EEG recording to check the participant's behavior to see if they were watching the screen and engaged in other activities. During the EEG recording, participants were only asked to watch the screen and respond to the images by pressing a like-dislike buttons. The EEG was recorded for all stimuli shown in Figure 1, only those marked with a red border in the figure are presented in this paper because the volume of data presented seems to be sufficient to evaluate the tested hypotheses.

Facial expressions

A total of four pictures were used in the condition focusing on the emotional response elicited by the presentation of faces with a particular emotional expression. Three of them expressed negative emotions (fear, anger, and disgust) and one positive one, containing a smiling face. The set used is shown in Figure 1A. These facial expressions have been used since 2010 and were pre-tested on the group of $N = 104$ using the E-prime software application with a four-button response box (each button marked with one emotion). Each expression was presented to the subject 25 times in random order; there were up to 2 s to respond. Average consistency responses (mean proportion consistent answers) were Anger = 94.16%, Fear = 84.46%, Disgust = 82.65%, and Smile = 96.27%. The male face was selected based on the findings of Adolph and Alpers (2010): "…more intense male expressions may be more potent in inducing emotional responses." The consistency in our set was generally higher than those of a large and detailed study performed by Tottenham et al. (2009).

Stimuli from the anamorphic software

With the consent of all participants, standardized photographs of their bodies in their underwear were obtained by trained medical staff and then uploaded to Anamorphic software (Symplex Information Solutions, United Kingdom). This software can identify and adjust the body's width in the embedded photograph. Next, participants were asked to use a mouse slider to create the body they would like to have (desired body) by modifying the original image, and then the body they thought matched what they actually looked like (perceived body). Finally, the two newly created and the original served as stimuli in a second condition, as shown in Figure 1B. Anamorphic software has been used for a long time in the department. We were not pre-testing these pictures to prevent priming or habituation. Each set was created for a particular participant based on images of her own body and her settings of the distorted (desired and estimated) versions. The pictures were then destroyed except for the one presented in Figure 1 (with the participant's permission). Participants first modified their photographs in the Anamorphic software, which were then entered into the stimulus presentation software by the research team. No EEG recording was performed while the photographs were being edited.

Data processing

Continuous EEG recording was filtered using a 30 Hz low-pass filter and a 0.3 Hz high-pass filter and divided into epochs according to stimulus type-100 ms from the stimulus presentation mark +1,000 ms. Next, epochs contaminated by eye

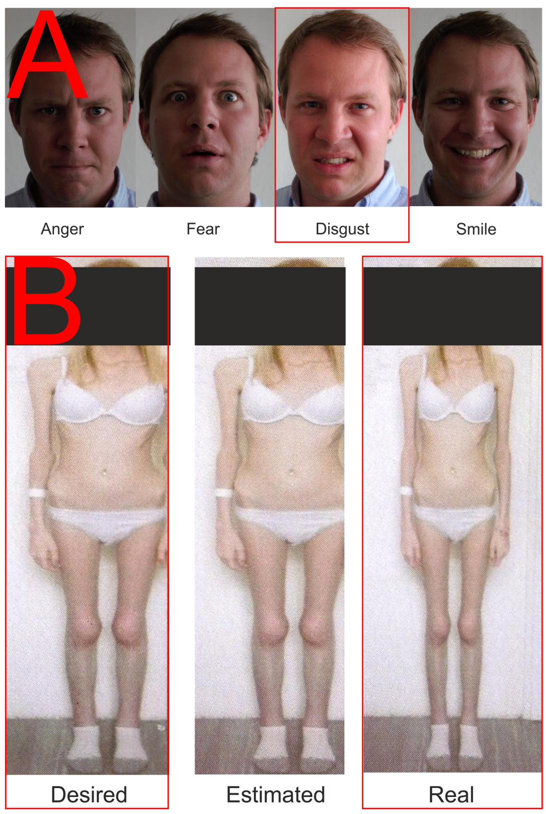

FIGURE 1
Examples of presented stimuli. **(A)** Facial expressions; **(B)** Body images. The red rectangle highlights the stimuli whose results are described in this paper.

or motion artifacts were eliminated, and individual bad channels were replaced segment by segment by spherical spline interpolation. Segments that passed all the above steps were averaged. Finally, averaged segments were re-referenced with a Polar Average Reference Effect (PARE) correction to estimate the zero integral of the surface potential (Junghofer et al., 1999) and adjusted to a baseline of 100 ms before the stimulus presentation marker.

Checking the meaningfulness of the measured data

Before performing the actual BAS processing, we wanted to make sure that the data obtained would have properties consistent with results presented in published studies using other technologies. Therefore, for verification, we computed both classical evoked potentials (not shown, they have been successfully published many times by other research teams), and further processed the data for display in fMRI format as shown in Figure 2. The results of these two ancillary computations were then compared with the results of previously published experiments on the same topic. The comparison results are discussed in more detail in the first part of the Discussion paragraph.

Data processing with the BAS method

The basis of the method is the calculation of the signal source from qEEG data. Sufficient accuracy of the digitized data is ensured in EEG recording by applying Nyquist's theorem, which determines the necessary sampling frequency depending on the frequency of the processed signal (Nyquist, 1928). The highest frequency recorded fell in the β-2 band, and the 500 Hz sampling rate used thus exceeded the minimum required by the theorem several times over. Similarly, in terms of the needs of the signal source algorithm, the spatial "Nyquist," specifying the minimum number of leads for qEEG recording, can be formulated. The minimum number of leads for brain gyrus-level computations reported in the literature is 60 (Srinivasan et al., 1998). The 128-channel technology used is twice the required minimum. The algorithm described by De Peralta et al. (2001) was used to compute the signal source based on the local autoregressive average (LAURA) calculation. The reason for choosing this particular algorithm is its output; LAURA does not focus only on

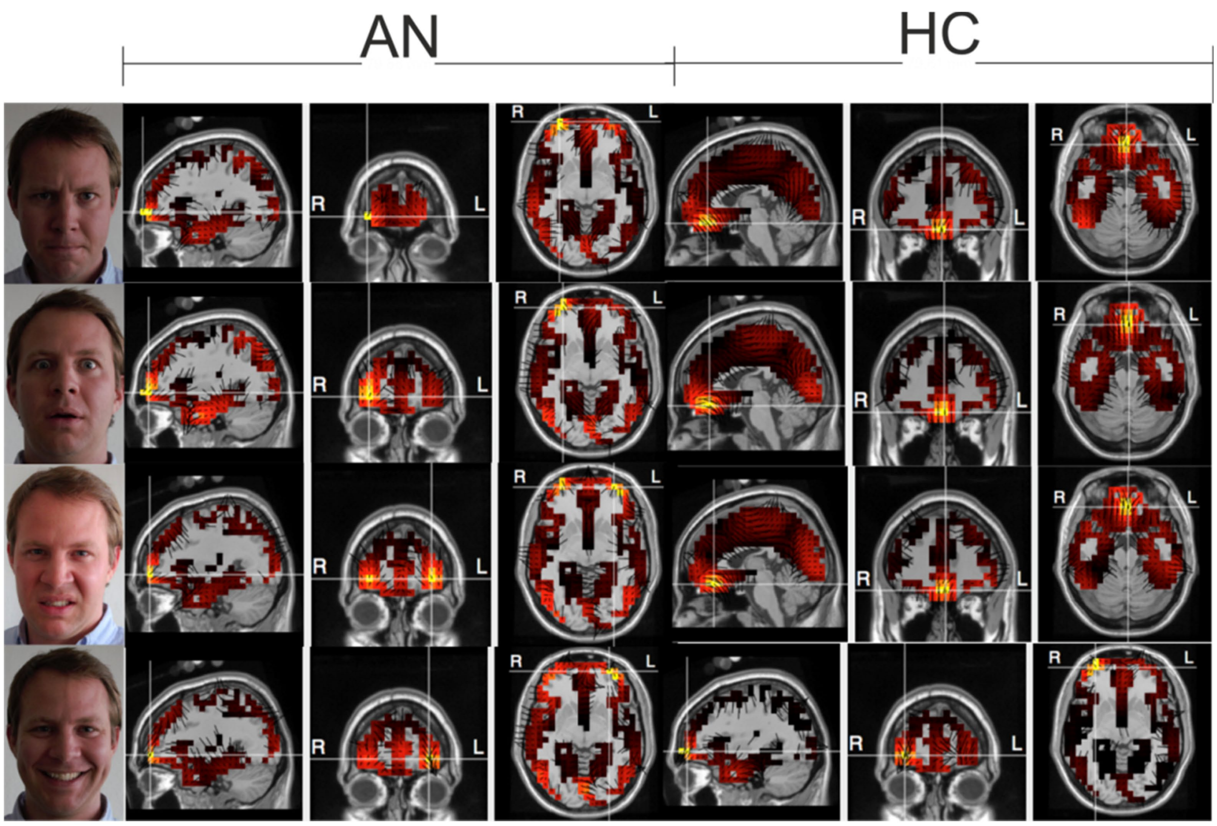

FIGURE 2
Electrical sources at the selected time as a check of the consistency of the measured data. Top-down Anger-Fear-Disgust-Smile, during maximal activation using the LAURA method. 2,400 voxels representing gray matter in the Montreal Neurological Institute average MRI (2,394 plus six thalamic sources) are registered in Tailarach space with a typical MRI image of the subject. Three orthogonal dipole moments are calculated for each voxel with linear inverse estimation. The color palette, which is kept constant for this series of images, reflects the effective value of the three dipole moments of each voxel.

the most intense source; it can calculate multiple signal sources at a given time (De Peralta-Menendez and Gonzalez-Andino, 2002). In the next step, BAS determines from all local autoregressive average data of all study participants a state space according to which it constructs and creates a system of differential equations expressing the dynamics of gyral activity. Each subject's data from the first stage of the computation (the signal source calculation) are then computed by the system of equations and the output is a sequence of gyri active at the time of stimulus processing. The output table contains only the record code; it does not indicate which group the output belongs to (AN, healthy controls). Thus, the software does not know whether it currently processes data from a participant with AN or HC. The BAS output table, which contains no information about group membership and only tells about the activity of individual brain gyri during stimulus processing, can be used as input for cluster analysis. The goal of the whole operation is to see if the cluster analysis partitions the unordered BAS output table according to group membership or, stated differently, whether it forms two clusters, one occupied by AN and the other by healthy controls.

A detailed description of the method was published in Susta et al. (2015), and the application of the technique to hypersomnias of central origin was described in Susta et al. (2016).

Results

Brain activation sequences provide two types of outputs. The first was described in the previous paragraph. It is a table illustrating the gyral activity of each study participant, and the second is a graphical representation of the same. The graphical representation, the output of which is shown in Figures 3, 4, is only for a cursory visual comparison of the measured values.

The original assumption that cluster analysis would form two clusters, one containing the outcomes of participants with AN and the other of healthy controls, was not confirmed. Instead, the output of the K-cluster analysis was three clusters, the first including only HCs, and the second and third containing study participants with AN.

As noted, the BAS output is a table with binary data on gyral activity during stimulus processing. After grouping them according to the cluster analysis results, it was possible to statistically evaluate the differences between the clusters. As this is a comparison of binary parameters, chi-square was used. Due to the high number of parameters being compared, there was a risk of a Type-I error, and a post-hoc Bonferroni correction was applied.

Table 2 shows the complete statistics of all results discussed in this paper. We deliberately do not report results for all stimuli and all combinations for two reasons. First, the extent of the results presented in detail, in our opinion, answers the research questions, and second, showing all the data would impose an unsustainable demand on the size and number of output elements. The Real and Desired columns refer to the Anamorphic condition, while the Disgust column contains the results of the Emotional Faces condition. The sub-columns labeled Final Cluster Centers contain the results of the cluster computation, and the adjacent column displays the Pearson chi-square and the exact two-sided sigma (p). The bottom two rows describe activity totals for the left and right hemispheres to answer the secondary question of whether the frequently reported right-sided dominance in AN is confirmed in the presented condition. Right hemisphere dominance was found in AN for the desired distorted body image and the emotional face expressing disgust, but not for the actual body image, where the right hemisphere was also dominant in HC.

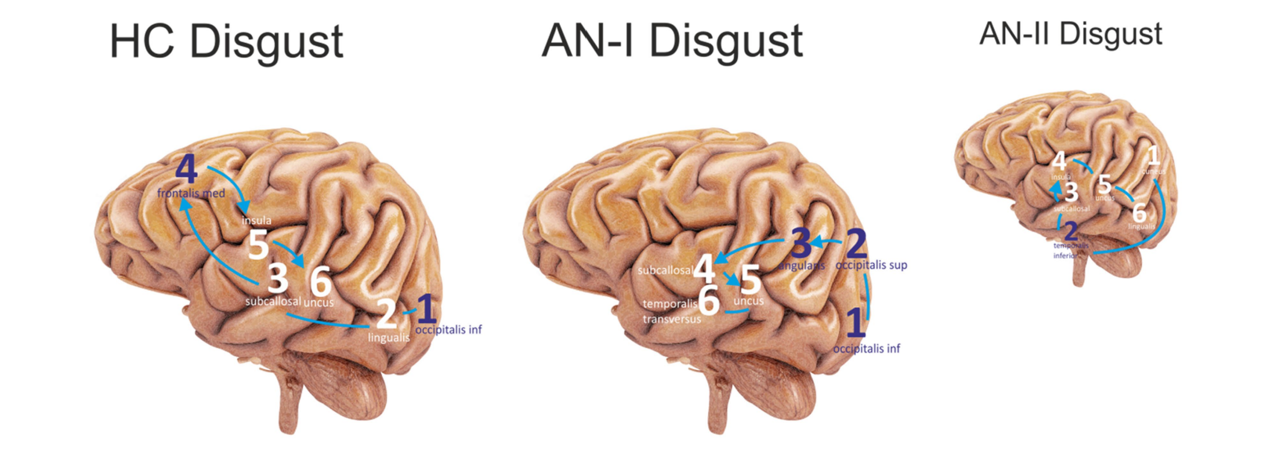

FIGURE 3
The first six sites that were most active in the Disgust condition were sequenced. The purple color represents the lateral sites, and the white color refers to the medial areas. Connecting lines without arrows show the same level of activity. HC Disgust refers to the HC group, AN-I Disgust refers to the AN-I group, and the smaller AN-II Disgust image refers to the AN-II group in results (Table 2).

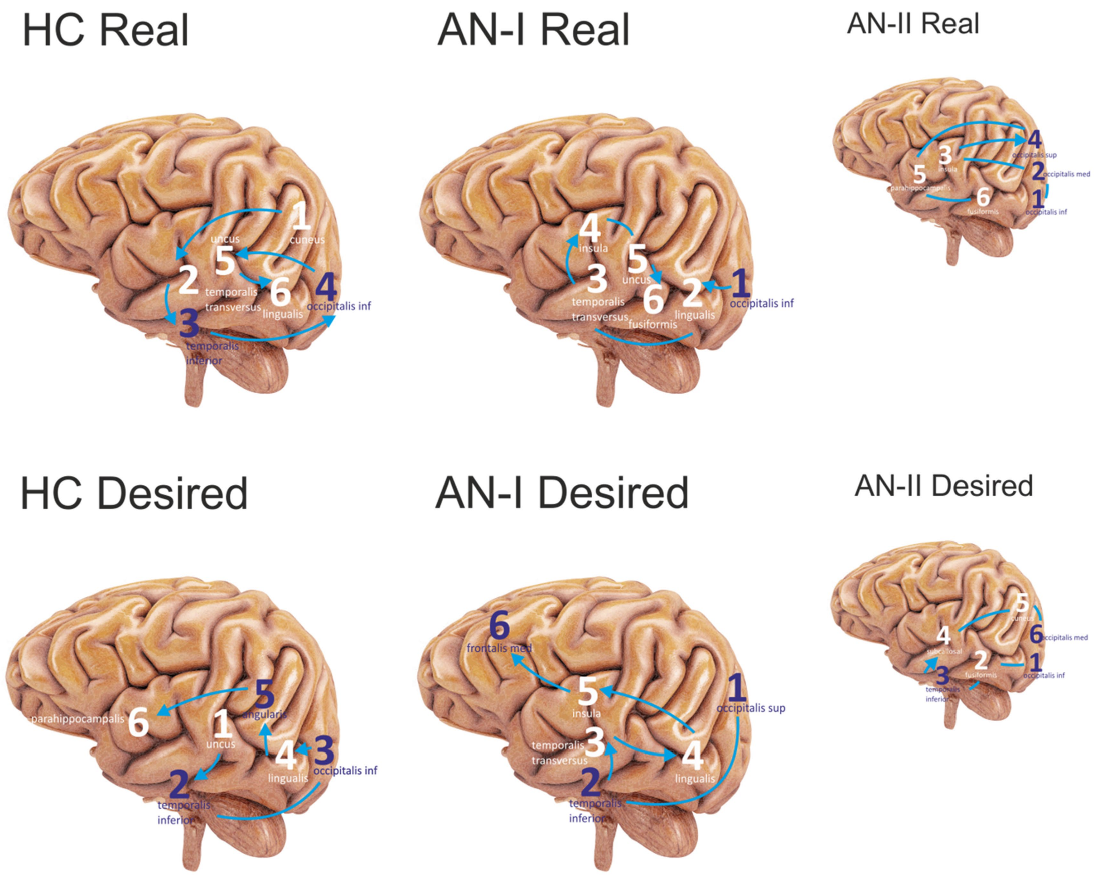

FIGURE 4
Sequenced the first six most active sites in the Anamorphic condition. Purple numbers represent lateral sites; white refers to medial sites. Connecting lines without arrows show the same level of activity at a given time. The HC corresponds to group HC, AN-I refers to group AN-I, and the smaller figure AN-II refers to group AN-II in Table 2. The upper group of figures describes the activity elicited by the Real body image, and the lower group the response to the distorted, Desired body shape.

For the disgust-expressing face condition, the results in Table 2 (AN-I vs. HC) show statistically significant differences, namely in the gyrus occipitalis inferior (left, right), occipitalis superior (right), lingualis (left), subcallosal (left, right), angularis (left), insula (left, right), temporalis transversus (left), fusiform gyrus (left, right), and frontalis medius (left). The first six most active locations are shown in the sequence in Figure 3.

The results of the condition with the participant's own body image are presented in the Real column of Table 2 (AN-I vs. HC) and show statistically significant differences between groups in response to the real body image in the cuneus (left), fusiform gyrus (right), insula (right), and temporalis inferior (right).

The results in the Desired column in Table 2 (AN-I vs. HC) show statistically significant differences between groups in the occipitalis superior (right), lingualis (left), insula (right), and temporalis transversus (left) in response to the distorted, supposedly desirable image of the body proper. Figure 4 then shows the gyrus sequences for both Real and Desired.

However, we consider dividing the participants' results into two clusters to be a result worthy of special attention. Anamnesthetically, no difference is evident between the members of the two clusters. This became apparent when the treatment outcome data were obtained. In the entire cohort of all 23 individuals with AN, there were only four who deteriorated during hospitalization. These four formed a separate cluster, designated as AN-II in the table. A *post-hoc* analysis showed substantial statistically significant differences between AN-I and AN-II across all three conditions. For the disgust-expressing face condition, both groups differed in occipital superior (right), occipital inferior (right), cuneus (right), angularis (left), insula (right), temporalis inferior (right), and lingualis (left). For the real body image condition, both groups differed in occipitalis superior (right), occipitalis medius (left), occipitalis inferior (right and left), uncus (left), temporalis transversus (right), insula (left), and parahippocampalis (right and left). For the real body image condition, both groups differed in occipitalis superior (right), occipitalis medius (right), occipitalis inferior (right and left), insula (right and left), lingualis (left), uncus (left), and parahippocampalis (right and left). For the desired body image condition, both groups differed in occipitalis superior (right), occipitalis medius (right), occipitalis inferior (right), uncus (left), cuneus (right), insula (right), temporalis inferior (right and left),

TABLE 2 Numerical results of the BAS outputs cluster analysis (Final Cluster Centers sub-columns) and Pearson chi-square (Pearson sub-columns).

Location	Real					Desired					Disgust				
	Final Cluster Centers			Pearson's		Final Cluster Centers			Pearson's		Final Cluster Centers			Pearson's	
	AN-I	AN-II	HC	Chi-square	*p*	AN-I	AN-II	HC	Chi-square	*p*	AN-I	AN-II	HC	Chi-square	*p*
Occipitalis Inferior L	0.00	1.00	0.00	44.00	0.000	-	-	-	-	-	0.05	0.00	0.90	32.88	0.000
Occipitalis Inferior R	1.00	0.00	0.86	24.77	0.000	0.00	1.00	0.90	36.74	0.000	0.95	0.00	0.05	36.25	0.000
Occipitalis Medius L	0.00	1.00	0.14	24.77	0.000	0.00	0.75	0.05	23.40	0.001	-	-	-	-	-
Occipitalis Superior R	0.00	0.75	0.00	32.19	0.000	0.95	0.00	0.00	40.08	0.000	0.95	0.25	0.05	33.31	0.000
Uncus L	0.84	0.00	0.86	14.97	0.002	0.79	0.00	1.00	22.77	0.000	0.74	0.75	0.76	0.03	1.000
Lingualis L	0.89	0.25	0.71	7.59	0.019	0.05	0.00	0.43	7.02	0.030	0.00	0.75	0.90	33.76	0.000
Lingualis R	0.00	0.00	0.05	1.21	1.000	0.89	0.00	0.76	14.13	0.001	0.00	0.00	0.05	1.12	1.000
Subcallosal L	0.00	0.00	0.14	3.52	0.307	0.05	0.00	0.33	6.26	0.044	0.11	0.00	0.90	29.57	0.000
Subcallosal R	-	-	-	-	-	0.00	0.75	0.05	23.40	0.001	0.79	1.00	0.05	27.42	0.000
Cuneus R	0.21	0.00	1.00	31.12	0.000	0.11	0.75	0.38	8.01	0.018	0.05	1.00	0.10	23.39	0.000
Angularis L	0.05	0.25	0.14	1.61	0.471	0.25	0.05	0.71	37.17	0.000	0.89	0.00	0.00	36.45	0.000
Angularis R	0.00	0.00	0.05	1.21	1.000	-	-	-	-	-	0.00	0.00	0.05	1.12	1.000
Fusiformis L	0.37	0.75	0.19	5.23	0.070	0.00	0.05	0.00	1.34	0.523	0.50	0.42	0.05	8.88	0.011
Fusiformis R	0.42	0.25	0.10	5.65	0.070	0.05	1.00	0.00	34.59	0.000	0.53	0.25	0.05	8.95	0.012
Insula L	0.21	1.00	0.14	13.44	0.002	0.11	0.25	0.05	1.74	0.432	0.05	0.25	0.43	7.51	0.022
Insula R	0.84	0.25	0.24	18.55	0.000	0.84	0.00	0.05	29.32	0.000	0.00	0.75	0.81	27.19	0.000
Temporalis Inferior L	0.53	0.00	0.62	5.16	0.093	0.95	0.00	0.90	23.39	0.000	-	-	-	-	-
Temporalis Inferior R	0.00	0.00	0.90	36.62	0.000	0.05	1.00	0.05	27.86	0.000	0.00	1.00	0.00	44.00	0.000
Temporalis Transversus L	-	-	-	-	-	0.89	0.00	0.00	36.45	0.000	0.74	0.25	0.05	33.31	0.000
Temporalis Transversus R	0.89	0.00	0.95	23.50	0.000	0.21	0.00	0.14	1.17	0.607	0.53	0.50	0.10	2.93	0.257
Cingularis Posterior R	0.16	0.00	0.05	1.91	0.326	-	-	-	-	-	0.05	0.00	0.05	0.22	1.000
Parahippocampalis R	0.00	0.75	0.05	23.40	0.001	0.32	0.00	0.62	20.20	0.000	0.00	0.00	0.10	2.29	0.578
Frontalis Medius L	-	-	-	-	-	0.37	0.50	0.19	2.40	0.340	0.00	0.00	0.86	33.36	0.000
LH activity	2.90	4.25	2.95			3.09	1.10	3.47			3.08	2.42	4.86		
RH activity	3.52	2.00	4.24			3.80	5.00	3.14			3.85	4.75	1.43		

The bottom two rows contain the sum of left and right hemisphere gyri. AN-I $N = 19$, AN-II $N = 4$, and HC $N = 21$.

temporalis transversus (left), supramarginalis (right), subcallosal (right), and fusiformis (right).

Discussion

Considering the results of the analyses carried out, the discussion focuses on three main themes: (1) disgust condition, (2) anamorphic condition will compare specifically AN-I group and HC group because of statistical robustness, and (3) findings related to the relatively small but clinically extremely interesting AN-II group.

Results from the Disgust stimulus condition confirm the right hemisphere (RH) dominance reported by numerous research groups (Grunwald et al., 2004; Galusca et al., 2008; Trautmann-Lengsfeld et al., 2013). The source localization algorithm does not involve subcortical structures; the activity of the limbic system is accessible only indirectly through sites with solid connections to its prominent parts. Insula integrates projections from the lateral and basolateral amygdala (Gogolla, 2017). High visual cortex and low limbic system activity, together with increased fusiform gyrus activity in AN, confirm conclusions published by Harrison et al. (2010) and Ashwin et al. (2006), suggesting the existence of social attentional bias toward faces while the emotion remains undetected. Interestingly, this finding is in line with the observed impairments in emotion recognition and avoidance of emotional faces in non-clinical population with high scores on Eating Disorder Inventory (Sharpe et al., 2016).

Insula is extensively mentioned in papers as a site highly active during processing disgust (Jabbi et al., 2008; Verstaen et al., 2016). High insular activity, the involvement of the medial frontal gyrus, low fusiform gyrus activity, and more moderate visual cortex activity in HC compared to AN indicate that the stimulus is perceived by healthy participants primarily as an emotion, not as a face. From a psychological perspective, these findings are in line with the observations associating low levels of mentalization and the ability to understand another person's perspective with the development of AN (Rothschild-Yakar et al., 2010).

Moreover, it is worth to note a substantial overlap (75%) between the active regions reported in Table 2 and brain circuitry identified by Sato et al. (2019), who studied individuals with Autism Spectrum Disorders using dynamic facial expressions. A morphometric experiment by Bjornsdotter et al. (2018) discovered lower temporal grey matter volumes in ASD. Our findings in the AN-II group show low activity in temporal regions that could be explained by the presence of ASD traits.That might help to explain the differences in interactions between limbic and cortical structures in AN and HC discussed above.

The Anamorphic condition with real and distorted desired body images confirmed RH dominance for the desired stimulus but not for the actual image of the subject's body. Reaction to the real image in AN-I and HC differs mainly in limbic system activity, but both groups utilize brain regions connected to anxiety and fear.

Participants with AN show elevated activity in the fusiform gyrus and right insula, confirming the findings of Seeger et al. (2002), indicating an activation of the brain's "fear network." Similar, but a weaker reaction to the real body stimulus in HC, including fusiform gyrus, right parietal areas, and left cingulate with limbic system activity correlates with anxiety generated by the task of judging a person's own body. Even in healthy women, body image and anxiety mechanisms are implicated in these tasks (Miyake et al., 2010; Frank and Kaye, 2012).

Response to the desired image differs from the real stimulus in fusiform gyrus, parietal and limbic system activity. The aforementioned study by Seeger et al. (2002) also found high activity in the amygdala and fusiform gyrus in response to distorted body images. In contrast, a subsequent study with the same design found activation not in the amygdala but in frontal and parietal regions thought to be involved in integrating body schemas and body ownership (Wagner et al., 2003).

Our study discovered activity in the limbic system and the frontal and parietal regions. That, together with inactive fusiform gyrus, might suggest a pending process of body evaluation accompanied by an emotional response that differs between AN-I and HC groups (Paslakis et al., 2021). The reaction to the image in AN-I, similar to defective pain sensation, confirms erroneous own body perception associated with anxiety and fear that often leads to self-hatred and various forms of auto-destructive behavior as a result of malnutrition, lack of self-acceptance, and traumatization (Cucchi et al., 2016; Yamamotova et al., 2017). The aversion reaction detected in the participants from the AN-I group in response to the "desired" image of their bodies (Figure 1B) may have arisen as a result of the therapeutic interventions from which the participants concluded that this is how they should look, however, their internal beliefs were still in conflict with an image significantly broader than the reality. In the healthy controls, the "desired" image was always thinner than reality, but the data showed that the discrepancy between perceived reality and the "desired" shape did not evoke any significant emotion. The "desired" body image was subsequently commented on by some with the words: "It would be nice, but I think I look good already."

Differences in utilization of the parahippocampal gyrus addressed the study of Shirao et al. (2003), who found its negative relation to the Eating Disorders Inventory-2 score.

The attempt to understand and possibly interpret the distinct differences between the two cluster in participants with anorexia is necessarily limited at the current stage of our knowledge because of the following factors: (1) cluster analysis is performed on a complex dynamics system which by itself make any traditional (mechanistic) analogies inappropriate, (2) no EEG studies are using the same protocols (to the best of our knowledge), leaving us with the options of indirect comparisons with fMRI literature, however (3) without any studies focusing on differences of functional pattern in a group of participants with AN from the treatment response perspective.

The list of the most active regions during real-body and desired-body conditions is consistent with the findings of the review article by Esposito et al. (2018), which shows that fMRI studies using body image perception and body size estimation tasks suggest modifications in the activity of the extrastriatal body region, fusiform body region, and parietal cortex. However, as with the fMRI studies reporting that the distinction between anorexic participants and controls was not clear, our findings did not allow us to follow up on the conclusion of differences between AN-I and AN-II when considering specific regions, including the superior occipital area, the angular gyrus, and the fusiform gyrus.

The pattern of activation in the desired-body condition found in both groups is consistent with Suchans' finding (Suchan et al., 2013) describing a correlation between right-sided fusiform activation and incorrect body size, suggesting that one of the differences between AN-I and AN-II could be related to the more pronounced dysfunction in the treatment-resistant group.

In addition, the differential activation of the gyrus lingualis and cuneus between groups in all three conditions may further suggest differences in attentional control and impairment from self-referential processing, as these structures are involved in attention and avoidance coping in anorexia fMRI studies by Noda and Isobe (2021).

Regarding the disgust condition, the two groups differed mainly in the predominant activation of the insula, temporal region, and cuneus in AN-II, whereas none of these areas were active in AN-I. This pattern of activity is consistent with the accentuated response to the disgust cue in the treatment-resistant group, allowing us to hypothesize that if self-disgust does not change during AN treatment, residual levels of self-disgust could contribute to treatment resistance and make individuals vulnerable to relapse (Glashouwer and de Jong, 2021).

Finally, it seems interesting to note that although a functional study is lacking, a morphometric study by Favaro et al. (2015) found that participants with anorexia with poor 3-year treatment outcomes had significantly lower baseline gyrification compared to healthy controls and participants with full recovery at follow-up, even after controlling for the effects of disease duration, weight loss, and age of onset, supporting the idea of substantial differences in the neurobiology of treatment response suggested by our findings.

Study limitations

We are aware that the number of participants may seem low to some. It should be noted that we tried to ensure as much homogeneity of data as possible, including identical therapeutic procedures, and so all participants admitted to the inpatient part of the AN unit at given time were included in the experiment. We wanted to ensure that any heterogeneity in outcomes was not attributable to the fact that some participants with AN had been treated by other psychiatrists or had participated in psychotherapy in another group or under the guidance of other therapists. Although discharge dates varied, all AN participants in the experiment were hospitalized and treated during the same period and thus interacted with the same medical and therapeutic personnel. It is clear that far-reaching generalizations cannot be made. On the other hand, AN-II group appeared to fully correlate with a treatment failure rate of 17.4%, reported by other specialized eating disorder treatment units.

The experimental results look promising, but the method used is new, and much more testing is needed to validate it in the ED. In addition, both samples were relatively small, and participants were medicated in many cases. This, together with the imperfection of the source localization method, the accuracy of the dynamic structure, and the unstable influence of the stimuli on different subjects, requires great caution before making a final judgment.

Drugs used to treat some participants are known to affect the EEG recording. Studies on the effect of antidepressants are rare, mostly available for sleep EEG, and their results are inconsistent. Most authors report a moderate effect on alpha and beta bands based on dosage or no effect (Banoczi, 2005; Dumont et al., 2005). In terms of the potential impact of medication, we could certainly consider involving only drug-naive participants or discontinuing medication for a necessary period of time, but we wanted to conduct the experiment in a realistic setting and not compromise the treatment process in any way. Therefore, we list the effect of medication as a potential limitation, but the degree of influence remains unknown.

A limitation of EEG as a primary data collection method is the known susceptibility to artifacts, which hinders the use of the design in restless subjects. Research groups equipped with qEEG amplifiers compatible with fMRI could substantially advance the search for a unified model of AN by obtaining spatially and temporally accurate data.

Further research is needed to show what exactly activation of specific regions means. The same question applies to the magnitude of inter-and intra-individual differences. Still, there is a chance that this or a similar method, considerably cheaper than fMRI or equivalent neuroimaging methods, could 1 day serve as a tool to predict treatment outcomes or to guide individualized treatment plans, perhaps as an alternative to fMRI-guided rTMS protocols for treatment-resistant anorexia.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee of the First Faculty of Medicine, Charles University, Prague, CZ. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

MS and GB: study design, acquisition, analysis, interpretation, and manuscript. AY and SP: study design, interpretation, and manuscript. MK: acquisition, analysis, and manuscript. HP: study design, analysis, interpretation, and manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Efficacy and mechanism of intermittent fasting in metabolic associated fatty liver disease based on ultraperformance liquid chromatography-tandem mass spectrometry

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Objectives: Drug treatment of metabolic associated fatty liver disease (MAFLD) remains lacking. This study analyzes the efficacy and mechanism underlying intermittent fasting combined with lipidomics.

Methods: Thirty-two male rats were randomly divided into three groups: Normal group, administered a standard diet; MAFLD group, administered a 60% high-fat diet; time-restricted feeding (TRF) group, administered a 60% high-fat diet. Eating was allowed for 6 h per day (16:00–22:00). After 15 weeks, liver lipidomics and other indicators were compared.

Results: A total of 1,062 metabolites were detected. Compared with the Normal group, the weight, body fat ratio, aspartate aminotransferase, total cholesterol, low-density cholesterol, fasting blood glucose, uric acid, and levels of 317 lipids including triglycerides (TG) (17:0_18:1_20:4) were upregulated, whereas the levels of 265 lipids including phosphatidyl ethanolamine (PE) (17:0_20:5) were downregulated in the MAFLD group ($P < 0.05$). Compared with the MAFLD group, the weight, body fat ratio, daily food intake, and levels of 253 lipids including TG (17:0_18:1_22:5) were lower in the TRF group. Furthermore, the levels of 82 lipids including phosphatidylcholine (PC) (20:4_22:6) were upregulated in the TRF group ($P < 0.05$), while serum TG level was increased; however, the increase was not significant ($P > 0.05$). Enrichment analysis of differential metabolites showed that the pathways associated with the observed changes mainly included metabolic pathways, regulation of lipolysis in adipocytes, and fat digestion and absorption, while reverse-transcription polymerase chain reaction showed that TRF improved the abnormal expression of *FAS* and *PPARα* genes in the MAFLD group ($P < 0.05$).

Conclusion: Our results suggest that 6 h of TRF can improve MAFLD *via* reducing food intake by 13% and improving the expression of genes in the PPARα/FAS pathway, thereby providing insights into the prevention and treatment of MAFLD.

KEYWORDS

metabolic associated fatty liver disease (MAFLD), intermittent fasting (IF), time-restricted feeding (TRF), lipidomics, triglycerides

Introduction

Non-alcoholic fatty liver disease (NAFLD), also known as metabolic associated fatty liver disease (MAFLD), has become the most prevalent liver disease worldwide. In 2016, a meta-analysis of 86 studies in 22 countries showed that the global prevalence of NAFLD was 25.2%, with Africa having the lowest prevalence at 13.5%, and the Middle East having the highest prevalence at 31.8%, followed by Asia at 27.4% (1–3). The prevalence of NAFLD in China has been reported at 29.2% (4). Although the risk of MAFLD increases with age (5), especially in women, an increasing number of cases of MAFLD have been reported in children. To date, no specific drug therapy has been established, and currently available treatments primarily focus on diet control and physical activity (6).

Intermittent fasting (IF) is an ancient dietary therapy characterized by zero or very low-calorie intake (usually for more than 12 h) alternated with normal eating to prevent or treat diseases (7). IF, which includes time-restricted feeding (TRF), alternate-day fasting, and 5:2 modified fasting, can improve metabolic syndrome, prolong life expectancy, and improve cognition (8, 9). However, data on the effectiveness of IF in improving MAFLD are limited, while controversy remains concerning whether IF aggravates MAFLD due to excessive fat breakdown.

Therefore, this study analyzes the food intake, therapeutic effect, and underlying mechanism in rats with MAFLD undergoing 6 h TRF to provide novel insights into the treatment of MAFLD.

Materials and methods

Animals and study protocol

Thirty-two specific-pathogen-free male Sprague-Dawley (SD) rats with a body weight of 185–245 g were purchased and raised in the Animal Center of Xi'an Jiaotong University [SYXK (Shaanxi) 2020-005]. After 1 week of adaptive feeding, 10 rats were randomly selected in the Normal group (262.4 ± 12.5 g) using the random number table method and fed a normal diet (10 kcal% fat); 12 rats were assigned to the MAFLD group (263.9 ± 20.1 g) and had unrestricted access to a high-fat diet (60 kcal% fat); 10 rats were assigned to the TRF group (264.7 ± 19.5 g), in which access to a high-fat diet (60 kcal% fat) was restricted from 16:00 to 22:00 daily. No significant difference in baseline body weight between the three groups was observed ($P = 0.958$). The high-fat diet was purchased from Changzhou SYSE BIO (China); the carbohydrate, protein, and fat energy accounted for 20, 20, and 60%, respectively. All rats had access to water *ad libitum* and were exposed to a 12:12 day:night cycle at a constant temperature of ∼22°C. During the 15-week experimental period, food intake was measured daily, while general conditions such as skin color, hair, and animal behavior were observed. The rats were weighed every week.

This study was approved by the Biomedical Ethics Committee, School of Medicine, Xi'an Jiaotong University (2021-763).

Biochemical parameters

At the end of week 15 and after overnight fasting for 12 h, the rats were anesthetized with an intraperitoneal injection of 1% pentobarbital sodium (40 mg/kg). Approximately 4 mL of blood was collected from the heart, incubated at room temperature for 1 h, and centrifuged at 3,500 rpm for 10 min to separate the serum. Fasting blood glucose (FBG), total cholesterol (TC), triglycerides (TG), low-density cholesterol (LDL), alanine aminotransferase (ALT), aspartate aminotransferase (AST), and uric acid (UA) were measured using an automatic biochemical analyzer (AU5811, Beckman Coulter, CA, USA). Body fat ratio was defined as = (epididymis fat + perirenal fat) / weight × 100%.

Histopathology

Hematoxylin-eosin (HE) staining (10, 11): Perirenal adipose and liver tissue samples from each group, ∼5 mm in size, were fixed in 4% paraformaldehyde, dehydrated, embedded in paraffin, sliced, stained with HE, and observed under a microscope as previously described (12).

Oil red staining: Liver tissue samples from each group, ∼5 mm in size, were fixed in 4% paraformaldehyde, dehydrated,

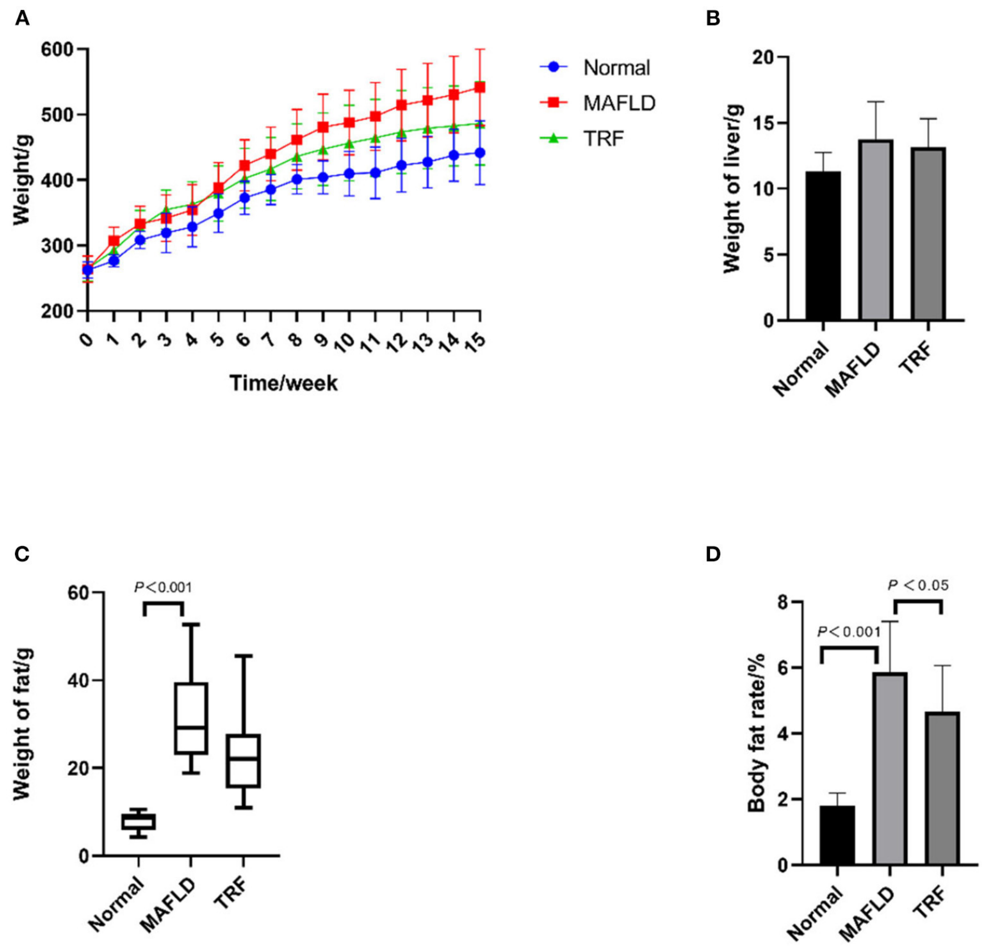

FIGURE 1
Physical characteristics. **(A)** Body weight from 1 to 15 weeks (g); **(B)** weight of liver (g); **(C)** weight of perirenal and epididymal fat (g); **(D)** body fat rate (%). The data are presented as means ± SD or percentile. Normal, rat fed a normal diet *ad libitum*; MAFLD (metabolic associated fatty liver disease), rat fed a high-fat diet *ad libitum*; TRF (time-restricted feeding), fed high-fat diet (60 kcal% fat) strictly only between 16:00 and 22:00 every day.

embedded in optimal cutting temperature compound, sliced, stained, sealed with glycerin gelatin tablets, and observed under a microscope. Four images were randomly selected from each section, and the tissue area occupied by lipid droplets, representing the fat content of the liver, was calculated using Image J software (v1.8.0, National Institutes of Health, USA).

Liver lipidomics

Using ultraperformance liquid chromatography and tandem mass spectrometry (UPLC-MS/MS) with Metware Database and multiple reaction monitoring (MRM), the lipid metabolites in all samples were qualitatively and quantitatively assessed. Quality control (QC) samples were prepared from a mixture of sample extracts. During instrumental analysis, one QC sample for every 10 test samples was inserted to ensure the repeatability of the analysis process. The total ion chromatograms (TICs) of different QC samples were overlapped and analyzed (13–15).

Principal component analysis (PCA) and orthogonal partial least squares discriminant analysis (OPLS-DA) were combined to identify differential metabolites. Metabolites with fold change (FC) of ≥ 2 or ≤ 0.5 and variable importance in the projection of ≥ 1 were selected as differential metabolites. Kyoto Encyclopedia of Genes and Genomes (KEGG) database was used to annotate and display the differential metabolites and analyze the related metabolic pathways (15).

Reverse-transcription polymerase chain reaction of liver

RNA was extracted using Total RNA Extraction Kit I (OMEGA, R6834-01). RNA concentrations were determined

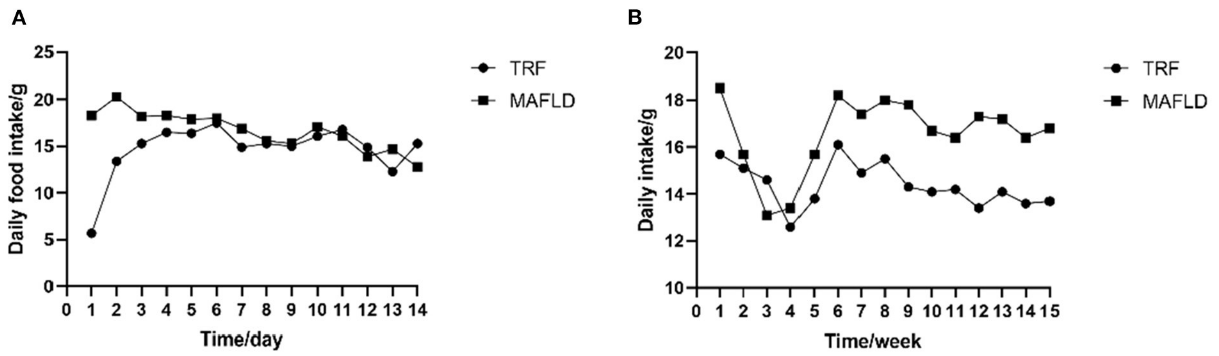

FIGURE 2
Feeding behavior. **(A)** Daily food intake of each rat from day 1 to 14; **(B)** average daily food intake of each rat from 1 to 15 weeks (g). MAFLD (metabolic associated fatty liver disease), rat fed a high-fat diet *ad libitum*; TRF (time-restricted feeding), fed high-fat diet (60 kcal% fat) strictly only between 16:00 and 22:00 every day.

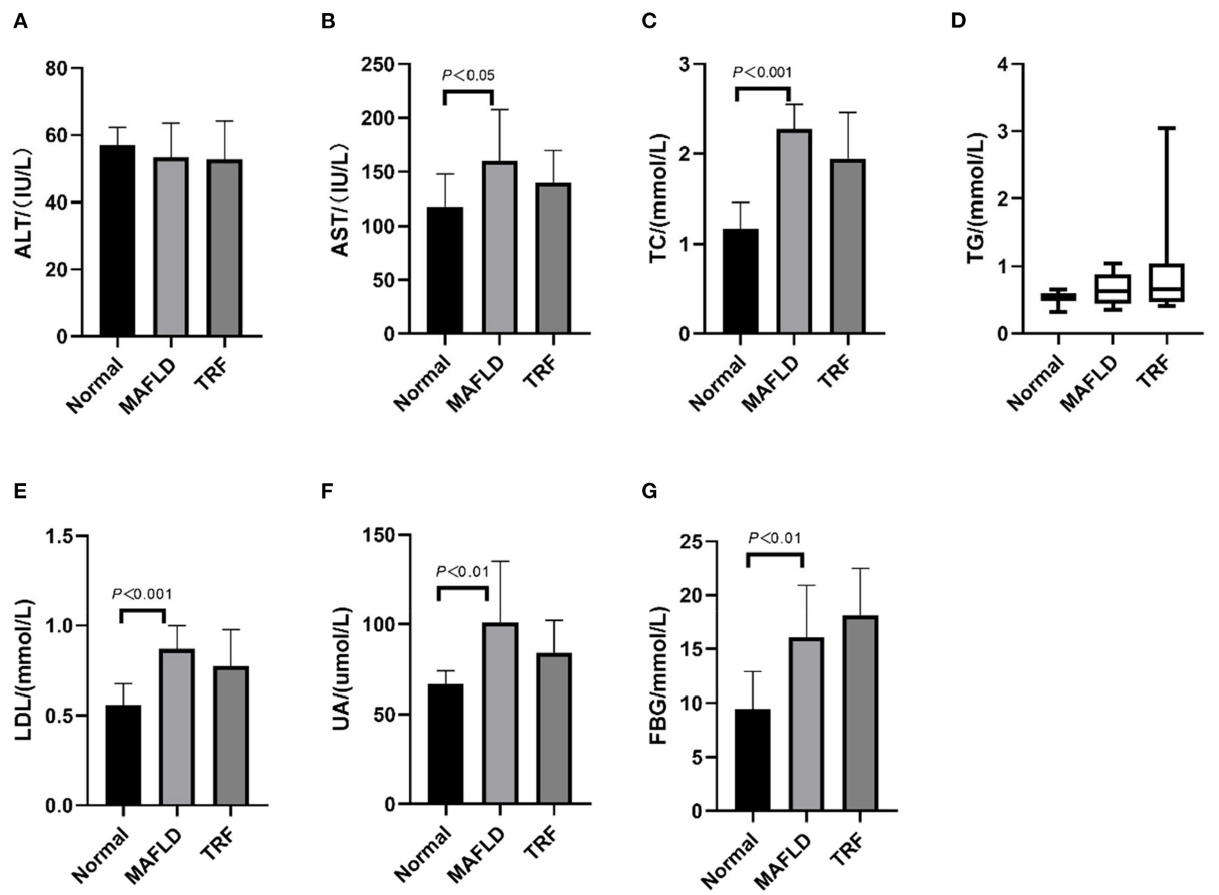

FIGURE 3
Serum indexes. **(A)** Alanine transaminase; **(B)** aspartate aminotransferase; **(C)** total cholesterol; **(D)** triglycerides; **(E)** low-density lipoprotein; **(F)** uric acid; **(G)** fasting blood glucose. The data are presented as means ± SD or percentile. Normal, rat fed a normal diet *ad libitum*; MAFLD (metabolic associated fatty liver disease), rat fed a high-fat diet *ad libitum*; TRF (time-restricted feeding), fed high-fat diet (60 kcal% fat) strictly only between 16:00 and 22:00 every day.

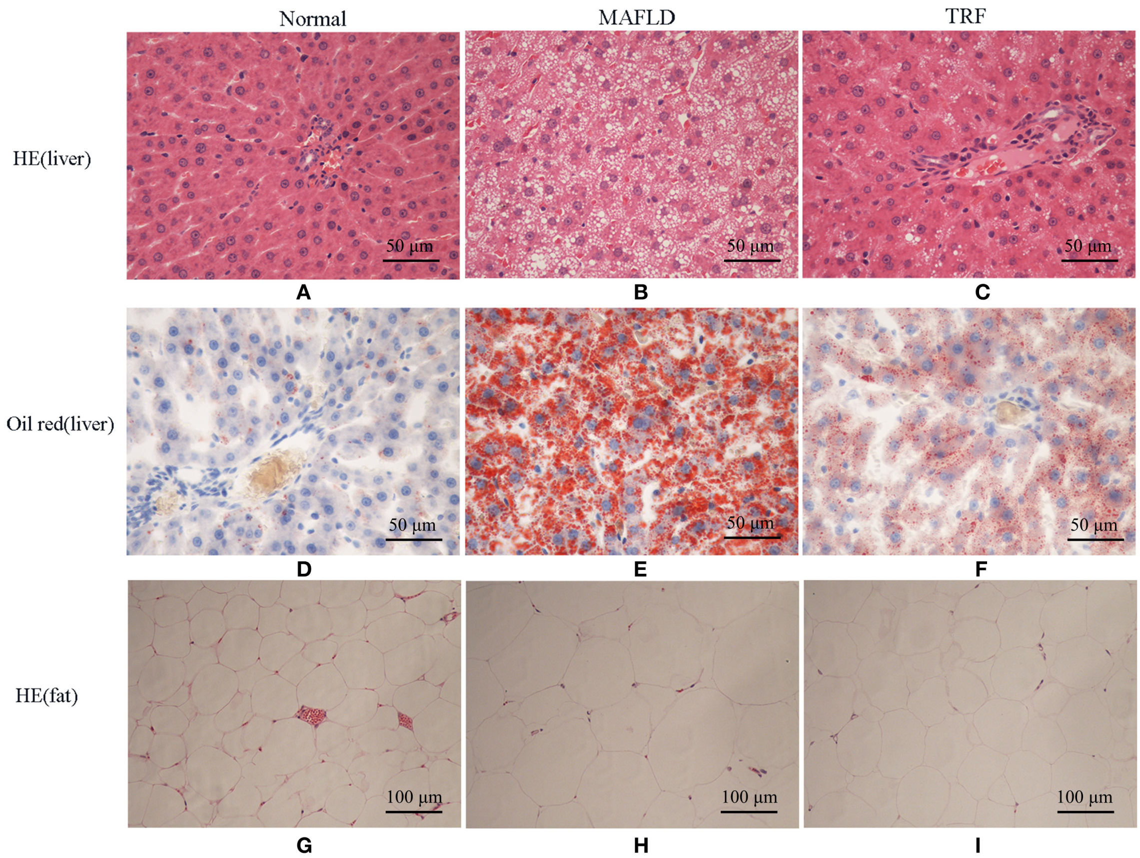

FIGURE 4
Pathological results of Normal group, MAFLD group and TRF group. **(A–C)** HE staining, **(D–F)** oil red staining of liver tissue (×400), and **(G–I)** HE staining of perirenal fat (×200). Normal, rats fed a Normal diet *ad libitum*; MAFLD (metabolic associated fatty liver disease), rats fed a high-fat diet *ad libitum*; TRF (time-restricted feeding), rats fed high-fat diet (60 kcal% Fat) strictly between 16:00 to 22:00 every day.

with spectrophotometric trace (NanoDrop, Thermo Fisher Scientific, Waltham, MA, USA). Total RNA was transcribed into cDNA (volume: 20 μL) following the manufacturer's instructions of PrimeScript RT Master Mix (TaKaRa, RR036A) and TB Green Premix Ex Taq II (TaKaRa, RR820A). We used ABI StepOne Plus (USA) to determine the relative abundance of the mRNAs of interest. All procedures were strictly conducted in accordance with the instructions. The expression of each gene was quantified using the $2^{-\Delta\Delta Ct}$ method (11, 16).

The primer sequences used were peroxisome proliferator-activated receptor α (*PPARα*) upstream primer (5'-3') TCTGAACATTGGCGTTCGCAG and downstream primer CTCGTGTGCCCTCCCTCAAG; fatty acid synthase (*FAS*) upstream primer (5'-3') AATTTGCTCGGCAGCACAAG and downstream primer GTCGCAGCGGTTAGCTTTTC; sterol regulatory element binding proteins-1c (*SREBP-1c*) upstream primer (5'-3') GCCATGGATTGCACATTTGAAGA and downstream primer TGTGTCTCCTGTCTCACCCC; glyceraldehyde phosphate dehydrogenase (GAPDH) upstream primer (5'-3') TACCCACGGCAAGTTCAACG and downstream primer CACCAGCATCACCCCATTTG.

Statistical analysis

Normally distributed data were expressed as mean ± standard deviation, and one-way analysis of variance was used, while Fisher's least significant difference *t*-test or Tamhane's T^2-test to determine significance. Skewed data were described *via* quartile spacing and compared using non-parametric and median tests. All rats were tested for routine parameters, such as body weight, body fat percentage, and serological indicators. No less than four biological replicates were considered for lipidomics and PCR.

Lipid data were analyzed using Analyst 1.6.1 software. The IBM SPSS 23.0 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses. GraphPad Prism 8.0 software (San Diego, CA, USA) was used to generate graphs. Statistical significance was set at $P < 0.05$.

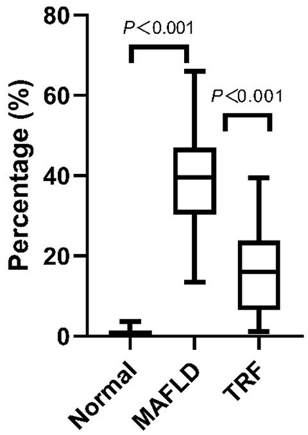

FIGURE 5
Area of lipid droplets in liver (%). Four images were randomly selected from each section, and the tissue area occupied by lipid droplets, representing the fat content of the liver, was calculated using Image J software (v1.8.0,National Institutes of Health, USA). The data are presented as percentile.

Results

Physical characteristics

As shown in Figure 1A, at the end of week 15, the body weight difference between the three groups was significant ($P = 0.005$), with rats in both the Normal group ($P = 0.001$) and 6 h TRF group ($P = 0.044$) weighing less than those in the MAFLD group. As shown in Figure 1B, there was no significant difference in liver weight among the three groups. As shown in Figure 1C, the fat weight of the MAFLD group was significantly higher than that of the Normal group.

As shown in Figure 1D, the body fat ratio of the rats in the three groups was significantly different ($P < 0.001$); indeed, the body fat ratio of the rats in the MAFLD group was significantly higher than that of the rats in the Normal group ($P < 0.001$) and TRF group ($P < 0.05$), suggesting that TRF reduced body fat.

Feeding behavior

The amount of food eaten was determined by subtracting amount of food administered from that remaining at the end of the eating period. As shown in Figure 2A, the food intake of rats in the 6 h TRF group was relatively low on day 1 after IF initiation; however, it increased significantly on day 2, as rats began to adapt to the fasting mode.

In the first 4 weeks of the study, the average daily food intake of both the MAFLD and 6 h TRF groups decreased, possibly due to rats not fully adapting to the high-fat diet, and subsequently increased on weeks 5–6 and remained relatively stable thereafter (Figure 2B).

During the entire experimental period, the average daily food intake in the 6 h TRF and MAFLD groups differed ($P < 0.001$), being 16.6 ± 1.6 g in the MAFLD group and 14.4 ± 0.9 g in the 6 h TRF group; ∼13% of total calories were restricted.

Biochemical parameters

As shown in Figure 3, after 15 weeks of a high-fat diet, AST, TC, LDL, UA, and FBG levels in the MAFLD group were significantly higher than those in the Normal group ($P < 0.05$), whereas in the 6 h TRF group, AST, TC, LDL, and UA levels were reduced. However, the difference was not significant ($P > 0.05$).

Compared with that in the MAFLD group, the serum TG level in the 6 h TRF group was increased, although not significantly ($P > 0.05$).

Histopathology

The Normal group showed normal hepatic cord structure and radially arranged hepatocyte morphology (Figure 4A). In the MAFLD group, the hepatic cord structure was disorganized, while the hepatic cells were significantly swollen. In most hepatic cells, vacuoles of varying sizes and numbers of lipid droplets were observed, while some cells showed obvious nuclear deviation (Figure 4B). The number of fat vacuoles decreased in the 6 h TRF group (Figure 4C).

Oil red staining showed that the liver cells of the rats in the Normal group were slightly stained with scattered, red-stained lipid droplets (Figure 4D), while in the MAFLD group, several bulla-like red lipid droplets were observed in the cytoplasm (Figure 4E); liver lipids were significantly less deposited in the 6 h TRF group (Figure 4F). Compared with the Normal group, the MAFLD group had significantly higher fat content ($P < 0.001$), whereas the 6 h TRF group had significantly lower fat content in the liver than the MAFLD group ($P < 0.001$; Figure 5).

The adipose cells of rats were arranged regularly and uniformly (Figure 4G), whereas in the MAFLD group, cells showed different sizes, and were disordered (Figure 4H). The adipose cells in the 6 h TRF group were arranged more neatly than those in the MAFLD group with uniform cell size (Figure 4I).

Liver lipidomics

The TICs of different QC samples were overlapped and analyzed. The results showed that the TICs of metabolite detection highly overlapped; the high stability of the instrument

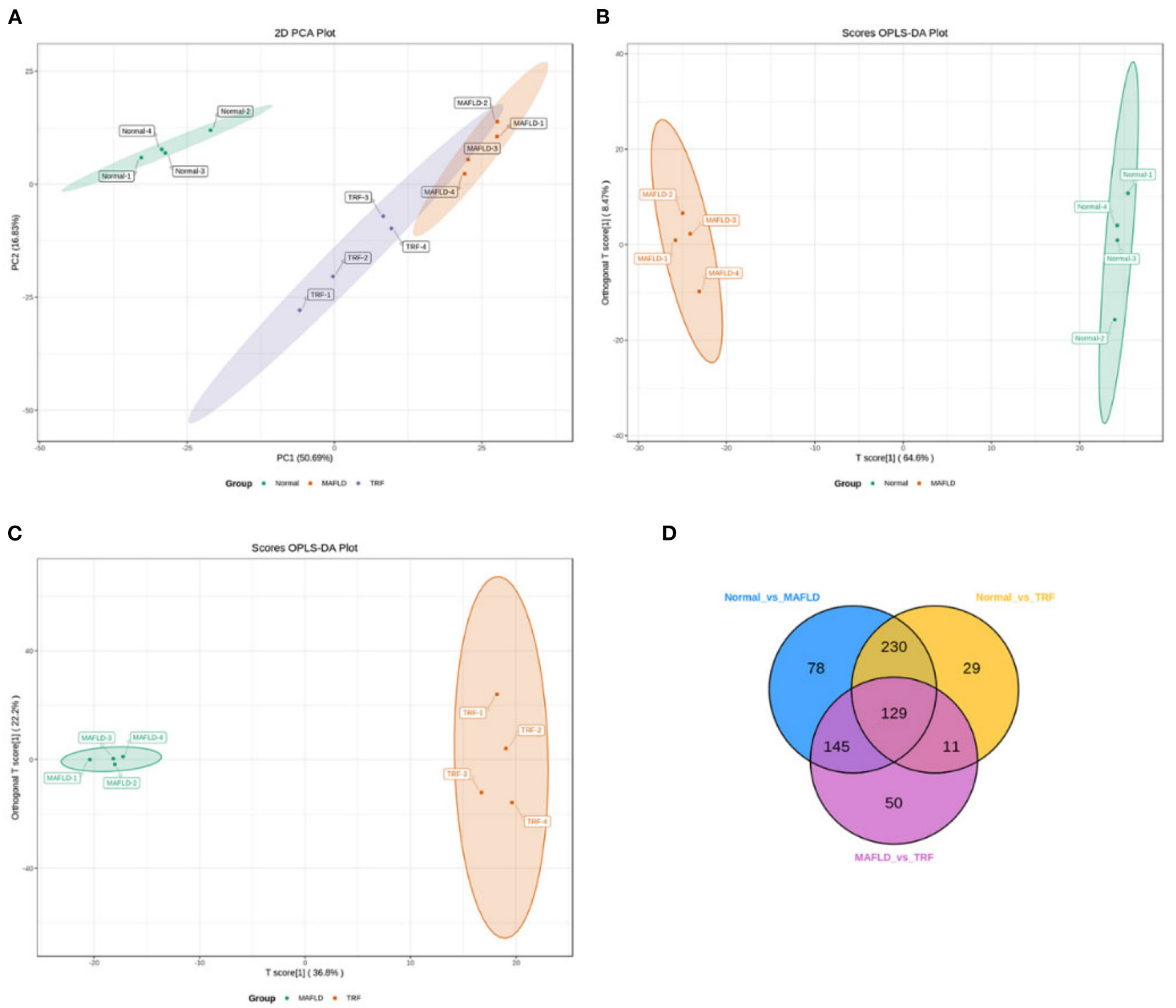

FIGURE 6
Liver lipidomics results. PCA for all groups **(A)**. OPLS-DA scores plots **(B,C)** of Normal vs. MAFLD and MAFLD vs. TRF, respectively. In the Venn diagram **(D)**, each circle represents a comparison group, the number of circles and overlapped parts represent the number of common differential metabolites between the comparison groups, and the number of non-overlapped parts represents the number of unique differential metabolites in the comparison groups. Normal, rats fed a normal diet *ad libitum*; MAFLD (metabolic associated fatty liver disease), rats fed a high-fat diet *ad libitum*; TRF (time-restricted feeding), rats fed high-fat diet (60 kcal% fat) strictly between 16:00 and 22:00 every day.

guaranteed the repeatability and reliability of the data. PCA showed that the samples demonstrated aggregation within the group and dispersion between groups, with a good sample identification which reflects the results of the subsequent analysis (Figure 6A).

The OPLS-DA models (Figures 6B,C) were qualified (Normal vs. MAFLD, $R^2X = 0.731$, $R^2Y = 0.999$, $Q^2 = 0.982$; MAFLD vs. TRF, $R^2X = 0.717$, $R^2Y = 0.996$, $Q^2 = 0.843$).

A total of 1,062 metabolites were detected. Compared with the Normal group, the levels of 317 lipids, including that of TG (17:0_18:1_20:4) were higher, whereas those of 265 lipids, including phosphatidyl ethanolamine (PE) (17:0_20:5) were downregulated in the MAFLD group ($P < 0.05$). Compared with the MAFLD group, the levels of 253 lipids, including that of TG (17:0_18:1_22:5) were lower, while 82 lipids such as phosphatidylcholine (PC) (20:4_22:6) were upregulated in the TRF group ($P < 0.05$; Figures 7, 8). There were 129 identical differential metabolites in the three groups (Figure 6D).

KEGG enrichment analysis of differential metabolites showed that the pathways involved in the observed results mainly included metabolic pathways, fat digestion and absorption, regulation of lipolysis in adipocytes, lipid and atherosclerosis, cholesterol metabolism, and glycerolipid metabolism (Figure 9).

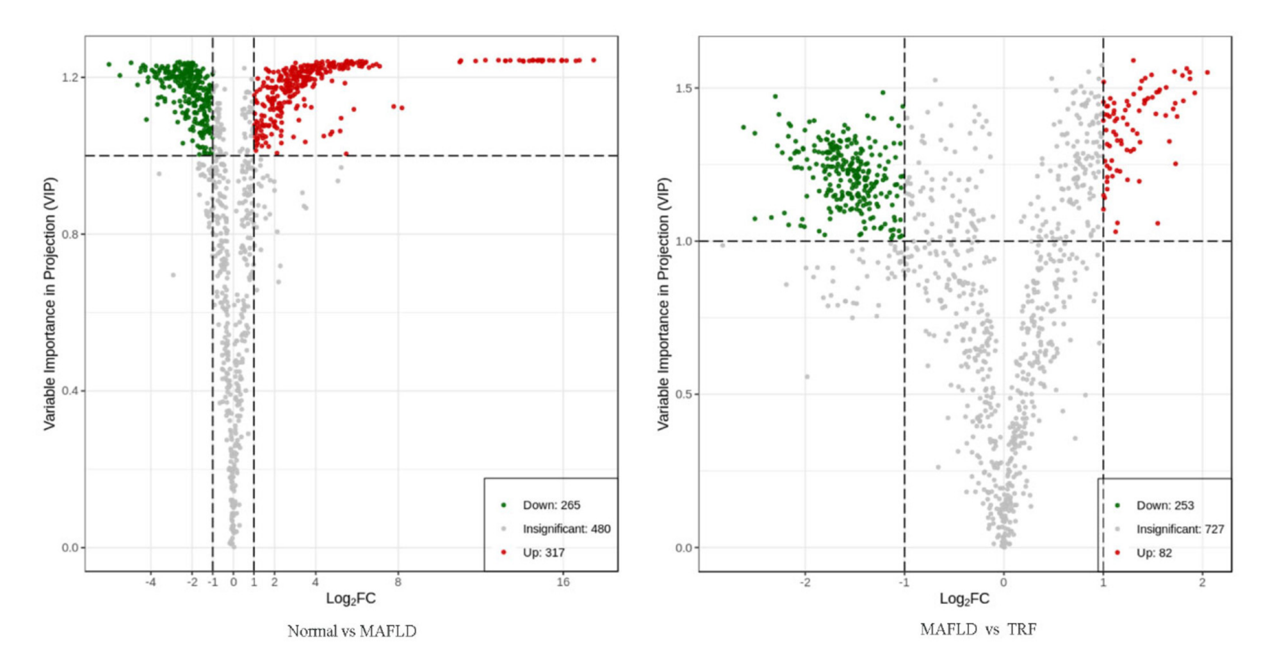

FIGURE 7
Volcano plot of differential metabolites in liver tissue. Using FC ≥ 2 or ≤ 0.5 and VIP ≥ 1 as criteria, a group of lipids with significant differences were screened. Lipids with significant differences are shown as red (upregulated) or green (downregulated) dots, while gray dots indicate lipids with no significant differences. Normal, rats fed a normal diet *ad libitum*; MAFLD (metabolic associated fatty liver disease), rats fed a high-fat diet *ad libitum*; TRF (time-restricted feeding), rats fed high-fat diet (60 kcal% fat) strictly between 16:00 and 22:00 every day.

Expression of genes associated with lipid metabolism in the liver

As shown in Figures 10A,B, the expression levels of lipid synthesis genes *SREBP-1c* and *FAS* in liver tissues were significantly higher in the MAFLD group than in the Normal group ($P < 0.01$), whereas the expression level of *FAS* in the 6 h TRF group was lower than that in the MAFLD group ($P < 0.05$).

Meanwhile, the expression level of the lipid oxidation gene *PPARα* in the MAFLD group was lower than that in the Normal group ($P < 0.05$). Compared with the MAFLD group, the 6 h TRF group had significantly higher *PPARα* expression level in the liver tissue ($P < 0.01$; Figure 10C).

Discussion

In this study, rats adapted to the 6 h TRF mode on day 2, and after 15 weeks of 6 h TRF, the average daily food intake for this group was reduced by 13%, while the body weight, body fat ratio, and liver fat content were lower than those of the MAFLD group. Hundreds of liver lipidomics also improved. Weight loss of 3%–5% within 1 year can improve metabolic syndrome and reverse simple hepatic steatosis, whereas a 7%–10% decrease in body mass can significantly reduce serum amino acid transferase levels and improve non-alcoholic steatohepatitis (6); our results suggest that a 6 h TRF can improve MAFLD.

Unhealthy lifestyles, such as excessive eating and lack of exercise, increase the risk of MAFLD (17). When the body takes in more calories than it burns, the excess calories are stored as fats. Additionally, dietary structure can promote the occurrence of metabolic diseases, such as MAFLD. Excessive intake of fat, cholesterol, and fructose can promote the occurrence of MAFLD; fructose consumption also increases the survival rate of intestinal epithelial cells, which in turn increases the length of intestinal villi, thereby allowing them to absorb more nutrients (18).

Calorie restriction (CR) limits the total number of calories and requires no eating schedule; conversely, IF places more emphasis on restricting the eating schedule, usually for more than 12 h, during which the body will undergo a metabolic switch to burn fat (19) and restore the body's internal clock, which can lead to weight loss and improve metabolic disorders (20–25). Circadian clocks and feeding times regulate the oscillations and levels of hepatic TG (26). Studies have shown that TRF resets the circadian clock in the liver and enhances the transcription of key metabolic regulators of sugar and lipid homeostasis, while dawn-to-sunset fasting is a potentially cost-effective intervention for obesity, metabolic syndrome, and NAFLD (27, 28). TRF can reduce the adverse effects of a high-fat diet by regulating the circadian rhythms of liver

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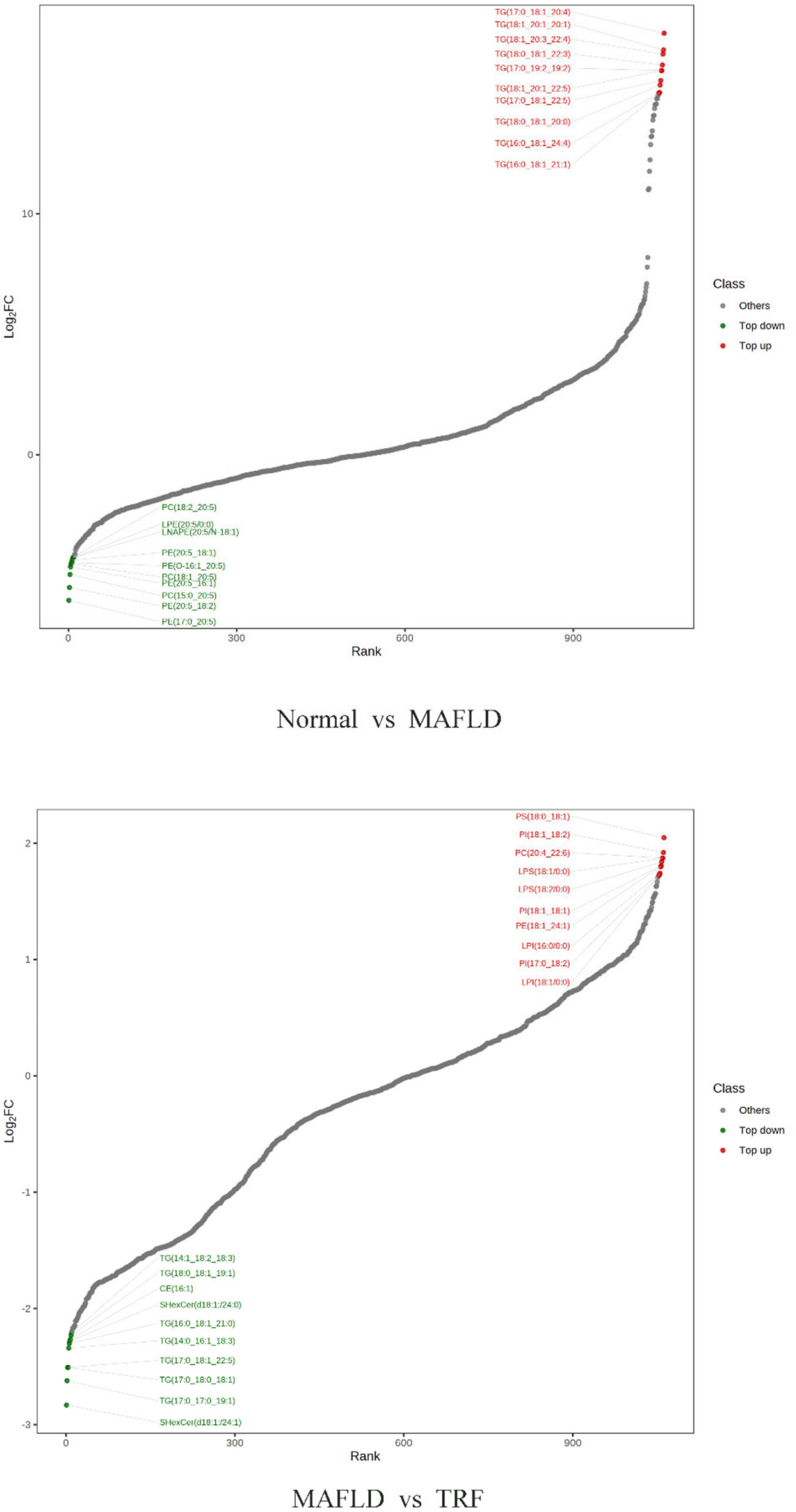

FIGURE 8
Ten differential metabolites with the most significant upregulation and downregulation in liver tissue. Normal, rats fed a normal diet *ad libitum*; MAFLD (metabolic associated fatty liver disease), rats fed a high-fat diet *ad libitum*; TRF (time-restricted feeding), rats fed high-fat diet (60 kcal% fat) strictly between 16:00 and 22:00 every day.

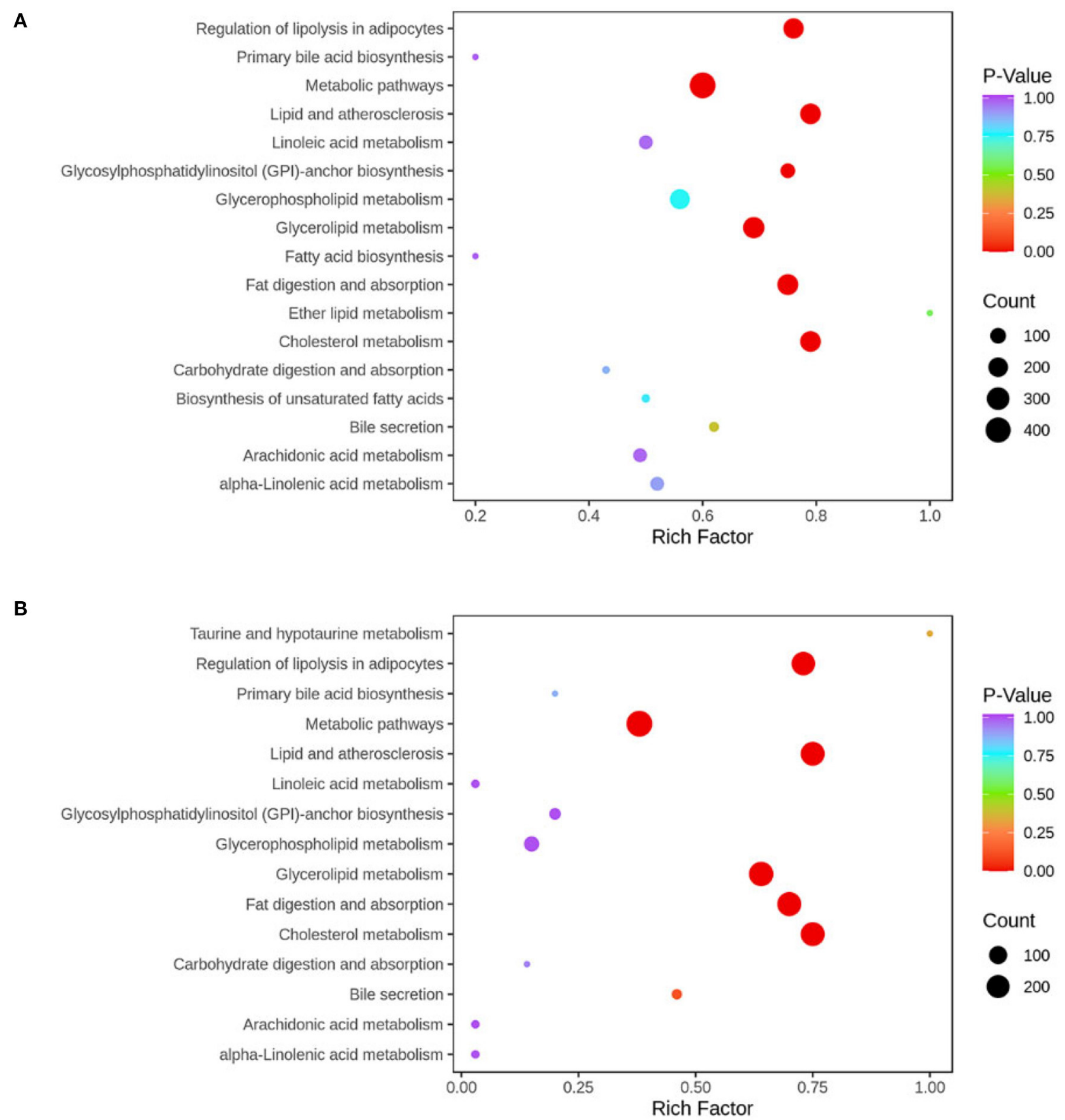

FIGURE 9
KEGG pathway was enriched according to the results of differential metabolites in liver tissue. The abscissa represents the Rich factor corresponding to each pathway, the ordinate represents the pathway name, and the color of the point indicates the *p*-value: the redder the point, the more significant the enrichment. The size of the dot represents the number of enriched differential metabolites. Normal, rats fed a normal diet *ad libitum*; MAFLD (metabolic associated fatty liver disease), rats fed a high-fat diet *ad libitum*; TRF (time-restricted feeding), rats fed high-fat diet (60 kcal% fat) strictly between 16:00 and 22:00 every day. **(A)** Normal vs. MAFLD; **(B)** MAFLD vs. TRF.

lipid metabolism and gut microbiota (29). Indeed, early TRF improves insulin sensitivity, blood pressure, and oxidative stress in men with prediabetes, even without weight loss (30).

The fasting duration of alternate-day fasting is 24 h, which may not be suitable for those with modern lifestyles. Alternatively, if the fasting duration is too short, the effect will be compromised. The 6 h TRF has little effect on work and life, and is similar to the long-standing dictum in China, "no food after noon", which is conducive to long-term adherence (31).

The results of this study show that compared with the MAFLD group, the 6 h TRF group had significantly higher *PPARα* mRNA expression in the liver tissue ($P < 0.01$). *PPARs* control various intracellular metabolic processes and contain three subtypes (32), of which *PPARα*, a member of the nuclear receptor superfamily, is the primary regulator

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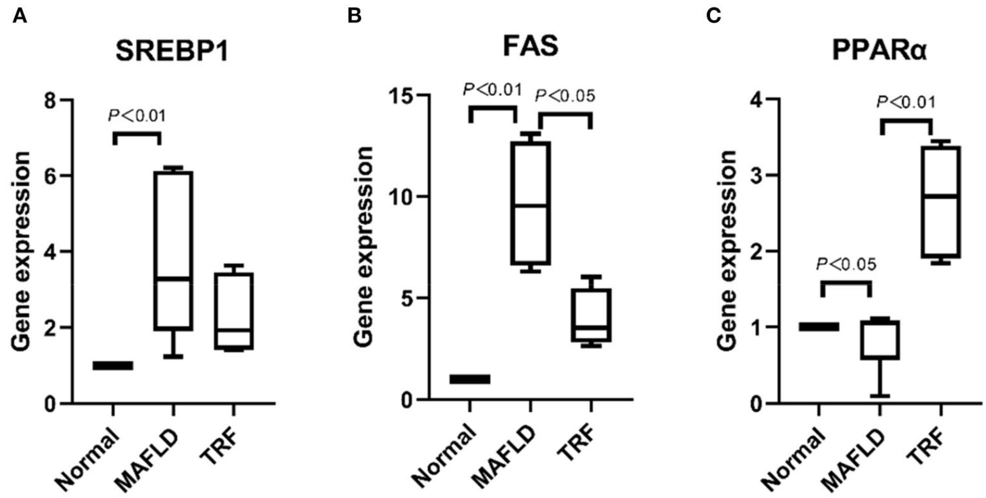

FIGURE 10
The mRNA levels associated with lipid metabolism in liver. **(A)** SREBP1, **(B)** FAS, and **(C)** PPARα. The data are presented as percentile. Normal, rats fed a normal diet *ad libitum*; MAFLD (metabolic associated fatty liver disease), rats fed a high-fat diet *ad libitum*; TRF (time-restricted feeding), rats fed high-fat diet (60 kcal% Fat) strictly between 16:00 to 22:00 every day.

of liver β-oxidation and microsomal ω-oxidation. Moreover, *PPARα* is involved in mitochondrial fatty acid β-oxidation. Using carnitine palmitoyl transferase-1 as a key enzyme, fatty acids can pass through the mitochondrial inner membrane to the mitochondrial matrix where they are metabolized. The activation of *PPARα* can reduce the production of TG and fat in the liver and improve MAFLD (33, 34).

Moreover, our results showed that the expression levels of *SREBP-1c* and *FAS* in liver tissues were significantly higher in the MAFLD group than in the Normal group ($P < 0.01$), whereas the expression levels of *FAS* mRNA were lower in the 6 h TRF group than those in the MAFLD group ($P < 0.05$). The *FAS* system is a key multi-enzyme complex in fat synthesis. The downregulation of *FAS* reduces fat synthesis, thus preventing or treating MAFLD (35, 36). *SREBP-1c* plays a major role in the control of lipid production by controlling the expression of several adipogenesis-related genes, and regulates lipid metabolism by promoting lipid synthesis by the liver and inhibiting its transport, while the downregulation of *SREBP-1c* expression restores the balance of liver lipid metabolism to normal (37, 38).

Exercise and hunger can promote *PPARα* (39), and changes in lipid metabolic pathways during fasting have been reported (9, 19). KEGG enrichment analysis of differential metabolites showed that the pathways involved mainly included glycerolipid metabolism, metabolic pathways, fat digestion and absorption, regulation of lipolysis in adipocytes, lipid, and atherosclerosis. Therefore, we compared the expression of fatty acid metabolism genes to determine the mechanism of 6 h TRF in the treatment of MAFLD. The results showed that, compared with the MAFLD group, the expression of *PPARα* in the 6 h TRF group was significantly increased, and that of the lipid synthesis gene *FAS* was decreased. Furthermore, by recording the daily food intake, which has not been performed prior to this study, we found that 6 h TRF reduced the daily food intake of rats ($16.6 \pm 1.6 > 14.4 \pm 0.9$ g, $P < 0.001$) compared with that of the rats that freely consumed a high-fat diet. This is another significant reason for the decrease in body weight, body fat ratio, and liver fat content in the 6 h TRF group, which is a novel finding of this study (40–42).

The 6 h TRF could reduce the trend of AST, TC, LDL, and UA levels increased with the high-fat diet, however, the difference was not significant. The results also showed that 6 h TRF could increase serum TG level, although not significantly. This suggests that 6 h TRF has no significant effect on the serological indices of MAFLD rats.

Nevertheless, our findings support the hypothesis that 6 h TRF can improve MAFLD; 6 h TRF can not only control the total caloric intake but also reshape metabolic rhythms and regulate the biological clock by restricting eating time. These results provide novel insights pertaining to the prevention and treatment strategies against MAFLD.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The animal study was reviewed and approved by the Biomedical Ethics Committee, School of Medicine, Xi'an Jiaotong University (2021-763).

Author contributions

JD: conception and design of the study. JD, DF, XJ, SZ, YL, XZ, MLi, MLu, CL, NG, JS, and SD: acquisition of data. JD, DF, and NG: analysis and interpretation of data. JD, JS, and SD: drafting the article. All authors have read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The nature and persistence of the effects of posthypnotic suggestions on food preferences: The final report of an online study

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The persistence of food preferences, which are crucial for diet-related decisions, is a significant obstacle to changing unhealthy eating behavior. To overcome this obstacle, the current study investigates whether posthypnotic suggestions (PHSs) can enhance food-related decisions by measuring food choices and subjective ratings. After assessing hypnotic susceptibility in Session 1, at the beginning of Session 2, a PHS was delivered aiming to increase the desirability of healthy food items (e.g., vegetables and fruit). After the termination of hypnosis, a set of two tasks was administrated twice, once when the PHS was activated and once deactivated in counterbalanced order. The task set consisted of rating 170 pictures of food items, followed by an online supermarket where participants were instructed to select enough food from the same item pool for a fictitious week of quarantine. After 1 week, Session 3 mimicked Session 2 without renewed hypnosis induction to assess the persistence of the PHS effects. The Bayesian hierarchical modeling results indicate that the PHS increased preferences and choices of healthy food items without altering the influence of preferences in choices. In contrast, for unhealthy food items, not only both preferences and choices were decreased due to the PHS, but also their relationship was modified. That is, although choices became negatively biased against unhealthy items, preferences played a more dominant role in unhealthy choices when the PHS was activated. Importantly, all effects persisted over 1 week, qualitatively and quantitatively. Our results indicate that although the PHS affected healthy choices through resolve, i.e., preferred more and chosen more, unhealthy items were probably chosen less impulsively through effortful suppression. Together, besides the translational importance of the current results for helping the obesity epidemic in modern societies, our results contribute theoretically to the understanding of hypnosis and food choices.

KEYWORDS

hypnosis, online supermarket, posthypnotic suggestions (PHSs), food choice, eating behavior, food preferences, Bayesian analysis, Bayesian generalized linear mixed model

1. Introduction

The increasingly obesogenic prevalent diets (Swinburn et al., 1999; Jaacks et al., 2019; Clark et al., 2022) in modern society (e.g., high in sugar or salt, high-fat red meat, ultra-processed food, "junk food") are posing threats to human health, biodiversity, and the climate. Therefore, there is an urgent need to shift toward more healthy diets (e.g., Willett et al., 2019). The rampant obesity epidemic demonstrates that traditional efforts toward diet change are insufficient (Pereira et al., 2005; Navarro-Allende et al., 2008; Kakoschke et al., 2017; Jones et al., 2018). Therefore, it is crucial to seek new ways to strengthen healthy food choices. Notably, food choices are subject to several interacting factors: food preferences, impulsive reactions, and cognitive control (Guerrieri et al., 2008; Nederkoorn et al., 2009, 2010; Bongers et al., 2015). Often, good intentions to eat healthy food disintegrate under the force of competing preferences or impulsive behavior. The traditional approach to diet regulations focuses mainly on unhealthy food restrictions through strengthening cognitive control, which showed limited success at best (for review, see Stephens et al., 2014; Yang et al., 2019). In the present study, we explore an alternative strategy and investigate the utility of posthypnotic suggestions (PHSs) in biasing food preferences in favor of a healthier diet.

Improving diet habits, which are already formed during sensitive periods early in life (Wilson, 2015; Maier-Noth, 2019), requires increasing the preference for and desirability of healthy food on an affective level (Zahedi et al., 2020a). The acquisition and modulation of food preferences and eating habits involve congenital factors, exposure (Bornstein, 1989), and a multitude of cognitive (Yang et al., 2019), affective (Zahedi et al., 2020a), social, and cultural influences (Enriquez and Archila-Godinez, 2021) that no single intervention can shoulder. However, PHSs can integrate cognitive and psychosocial factors and successfully change implicit food preferences toward more healthy options (Ludwig et al., 2014; Zahedi et al., 2020a). Nevertheless, previous efforts were (1) mainly focused on food preferences and not on actual food choices, (2) did not investigate the persistence of the effects, and (3) only recruited participants who were at least moderately responsive to hypnotic suggestions. These issues are addressed in the present study.

To better estimate the effects of PHSs in real-life-like situations, we utilized (I) an online supermarket mockup that included a large number of food items, and (II) measured subjective values for the same items. By measuring both subjective values and food choices, we were able to calculate choice-preference relationships. Choice-preference relationships in binary choices were analyzed using logistic regression modeling (McKerchar et al., 2009; Peng et al., 2010; Scherbaum et al., 2012). Choice-preference functions inform about choice biases (i.e., intercepts in the model) and dependencies of choices on preferences (i.e., slopes in the model). These results can be used to shed light on the underlying cognitive mechanisms of choice behavior. Additionally, (III) in order to address whether the effects persist over time, we re-tested the effects of the PHS after 1 week. Finally, (IV) to assess the generalizability of the previous results (Zahedi et al., 2020a), we recruited participants regardless of their responsiveness to hypnotic suggestions.

1.1. Hypothesis

Together, food choices, preferences, and choice-preference functions can be used to elucidate the mechanisms underlying the PHS effects. If choices and preferences for healthy food items are increased in the PHS-activated compared to the PHS-deactivated condition, but if the choice-preference function is unaffected, one can conclude that the PHS modulates choices by affecting explicit preferences. In contrast, if choices of healthy food items are increased but preferences are not, then a decrease in the choice-preference function's slopes or a positive choice bias may indicate that the PHS affects implicit food preferences that are not explicitly accessible. Finally, the increase in preferences without any modulation of choices but accompanied by increased slopes of the choice-preference function or induction of negative bias for healthy items indicates that the PHS can only affect explicit preferences that are insufficient for affecting choices.

Concerning unhealthy food items, if preferences and choices are decreased, a stable choice-preference function indicates that the PHS modulates choices by affecting explicit food preferences. In contrast, if choices of unhealthy food items are reduced but not preferences, an increase in slopes of the choice-preference function and/or a negative choice bias should be expected. This can be interpreted as related to an increased contribution of top-down cognitive control in food choices. Notably, for unhealthy food items, we expect any decrease in preferences to be accompanied by a decrease in choices.

Furthermore, we expected the PHS effects on food choice and food preferences to be stable across sessions. Finally, participants' hypnotizability should be correlated with the observed behavioral effects.

2. Materials and methods

2.1. Participants and inclusion criteria

Of the respondents to our advertisements, 55 (43 female, $mean\ Age = 26.9\ [19 - 39]\ years \pm 6.03$) were recruited in the study, of which 50 (38 female, $mean\ Age = 26.6\ [19 - 39]\ years \pm 5.70$) completed all three sessions. The minimum sample size of 40 participants had been based on a priori power analysis with $\alpha < 0.05$, $1 - \beta > 0.95$, $\eta_p^2 > 0.08$. The critical values were determined based on the suggestion of Cohen (2016), and the effect size was based on previous results (e.g., Zahedi et al., 2020a). Notably, Zahedi et al. (2020a) found a medium effect size of $\eta_p^2 = 0.22$. However, since only medium- and high-hypnotizable participants were included in that sample, we adjusted the expected effect size for the current study from medium, i.e., $\eta_p^2 = 0.22$, to small, i.e., , $\eta_p^2 = 0.08$. This adjustment ascertained that in the current study, where participants were included regardless of their hypnotizability scores, we have the statistical power to detect possible effects. Notably, the a priori power analysis, in tandem with the Bayesian statistics used, gives us the necessary tools to interpret possible null results appropriately, as well.

The exclusion criteria were being either underweight ($BMI < 18$) or obese ($BMI > 30$), or having a history of psychological or neurological problems. The criteria for healthy body weight were selected based on the recommendation of WHO (2022). However, all volunteers met the inclusion criteria, and therefore, no one had to be excluded (*mean BMI was* 22.0 [18.0 − 27.1] ± 2.40). The study was approved by the ethics committee of the Department of Psychology of the Humboldt-Universität zu Berlin (approval number 2021-36). Prior to the experiment, informed consent was obtained according to the declaration of Helsinki, and participation was compensated with 10 Euro/hour ($N = 25$) or course credits ($N = 30$). The study was conducted fully online.

2.2. Materials and tasks

The hypnotizability of participants was measured by the German version (Bongartz, 1985) of the Harvard group scale of hypnotic susceptibility—form A (HGSHS: A; Shor and Orne, 1962). In HGSHS: A, 12 different suggestions are delivered to participants, and their responsiveness is determined based on the number of items to which they could respond (based on self-reports). According to the scoring procedure suggested by Kihlstrom and Register (1984), scores between 0 and 12 can be achieved.

Other questionnaires to be completed were the Edinburgh Handedness Questionnaire (EHQ; Oldfield, 1971), the German Nutrition Knowledge Questionnaire (NKQ; De Souza et al., 2015), and the Self-Regulation of Eating Behavior Questionnaire (SREBQ; Kliemann et al., 2016). EHQ consists of 20 questions, evaluating which hand is usually used for administrating specific tasks, such as writing or throwing. The NKQ consists of 22 questions about the knowledge of healthy food choices and the sources of nutrients in food. The SREBQ consists of four questions aiming to evaluate an individual's capacity for regulating their eating behavior.

The online supermarket (Figure 1) was based on eight food categories, including 170 products in total. The organization and items were inspired by existing online shops and aimed to simulate real-life online food shopping behavior. For instance, a diverse array of options was presented for each product (i.e., full-fat and low-fat milk) to enable participants to choose their preferred items. The eight categories of food items in the supermarket are as follows:

1. Bread, rice, pasta, and other grain products (e.g., toast bread, pretzel, croissant),
2. Bread spreads and breakfast cereals (e.g., honey, jams, chocolate creams),
3. Eggs and dairy (e.g., milk, cheese, yogurt),
4. Convenience foods (e.g., filled pasta, pizza, potato salad),
5. Meat, poultry, fish, seafood (e.g., salami, minced meat, smoked salmon),
6. Fruits and vegetables (e.g., tomato, onion, pepper),
7. Sweets and salty snacks (e.g., chocolate, candy, ice cream, potato chips),
8. Oils, sauces, nuts, legumes (e.g., olive oil, cashew nuts, ketchup)

After choosing a food category, between 16 and 26 images per category were shown with the name underneath. Further, the nutrition facts for each item could be inspected by clicking a corresponding button on the screen ("Nährwertangaben"). Each item could be placed in the shopping basket by pressing a corresponding button on the screen ("in den Warenkorb legen"). The package sizes per item were relatively small, equal to approximately one serving; for example, participants could choose to buy a single egg or a single potato. However, there was no limit to the number of a given item that could be placed in the shopping basket. Also, participants could directly select a specific number (i.e., $1 \leq n \leq 20$) of each item. The shopping basket could be inspected to correct the number of items in the basket before placing the final order.

The online supermarket was introduced with the instructions that participants should imagine that they have to quarantine for 1 week. All food they wanted to consume during this period had to be ordered from the online supermarket. They had no budget limit and could choose as many products as desired. The only restriction was the time limit of 15 min for the supermarket task. The shopping task is publicly available for non-commercial use; please see Supplementary material for further information.

In the food preference rating task, participants were shown all the food items offered in the supermarket task in randomized order. Participants were to rate each item for how much they liked it in principle, independently of whether they wanted it at the moment. Ratings were performed on a Likert scale from 1 (Don't like it at all) to 7 (Like it very much). There was a response window of 20 s for each item, after which the trial was considered a miss. The food preference rating task required about 10 min.

2.3. Procedure

The experiment was conducted online *via* the Zoom platform and involved three sessions. All questionnaires were implemented through the SoSci Survey platform (Version 3.0. 01, www.soscisurvey.de), and the individualized links were sent to participants in real time during each session. In Session 1, written informed consent was obtained, and demographic information (i.e., age, sex, height, weight, educational background), NKQ, and SREBQ were collected. Afterward, the German version of HGSHS: A was administered to determine the hypnotic susceptibility of participants. We did not exclude any participants based on the screening results. Instead, susceptibility scores were used as a regressor in subsequent analyses. Session 1 took about 2 h and was conducted as an online group session with up to five participants. About 1 week (*mean* = 8.51 ± 1.26 *days*) after Session 1, Session 2 was conducted, lasting about 2 h, followed by Session 3 after 3–10 days (*mean* = 6.24 ± 2.28 *days*), which took about 1 h. In Sessions 2 and 3, participants were tested individually. Session 2 started with hypnosis that included a PHS aiming to induce a strong desire for healthy food. The hypnosis procedure and the employed PHS (for details, see Appendix A) were the same as in Zahedi et al. (2020a). Next, the food preference rating and the online supermarket were administrated twice, once with the PHS activated and once deactivated. The order of conditions (i.e., PHS activated and deactivated) was counterbalanced across participants. Session 3 was identical in its procedure to Session 2, except that no hypnosis was applied. The order of PHS activation and deactivation for each participant was the same as in Session 2.

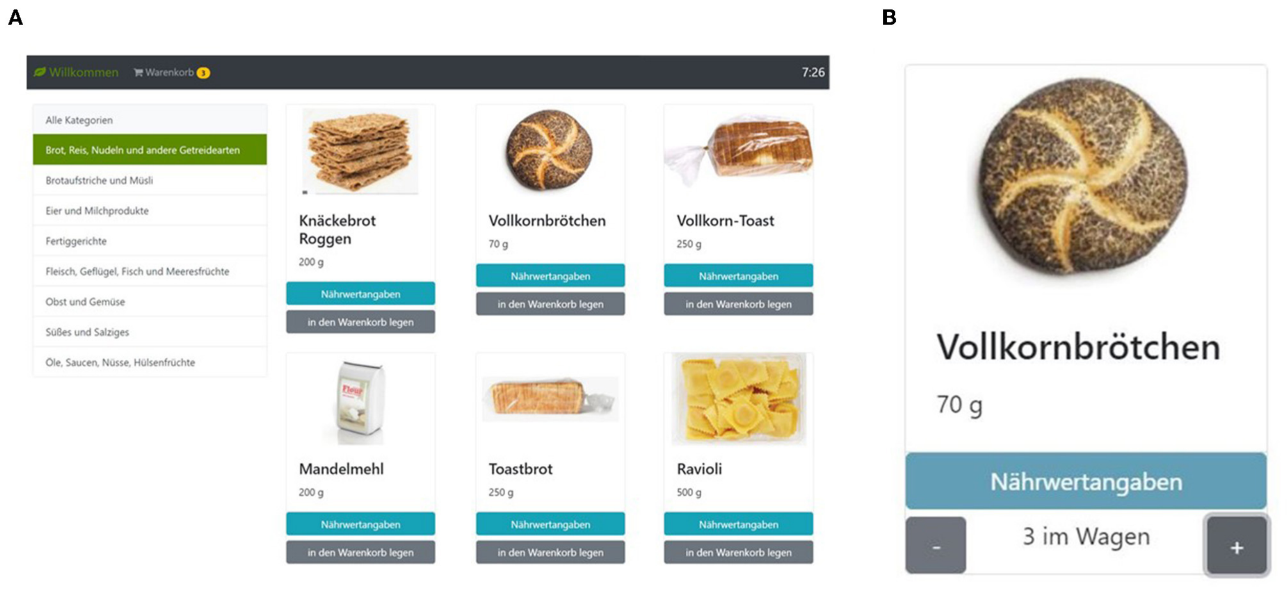

FIGURE 1
The screenshot of the supermarket task. **(A)** Participants could choose different food categories shown on the left side to see the items belonging to the respective category (in the example, the category 'bread, rice, pasta, and other grain products' has been selected). On the top right corner, the remaining shopping time is shown; on the top left, they can see their shopping basket ("Warenkorb"), which can be selected to modify its contents and place the order. **(B)** For each object, participants can choose to inspect the nutritional values ("Nährwertangaben") and select how many exemplars of the item they wish to put in their basket. The shopping task is publicly available for non-commercial use; please see Supplementary material for further information.

2.4. Data analysis

Based on our previous results (Zahedi et al., 2020a), we expected that posthypnotic suggestions would increase subjective preferences for healthy food items and decrease the subjective preferences for unhealthy food without affecting the choice-preference function. That means participants choose what they want based on the same principles as before, and therefore, the choice-preference function is unaltered. Thus, if preferences for healthy food items are increased, participants will choose more healthy food while the choice-preference function remains the same. Alternatively, choices may change, although preferences have not. In this case, the choice-preference function will also be affected, indicating that other mechanisms, such as increased suppression of temptation, must be considered as the driver of the changes. Finally, if preferences or choices of neutral food items (i.e., control items) were modulated, it reveals the opportunistic strategy used in response to experimental manipulation.

Independently from food categories, online supermarket items were categorized regarding their healthiness. Following Clark et al. (2019), we categorized the following items as healthy: (1) vegetables, (2) fruits, (3) legumes, and (4) some fish and marine products. Unhealthy food items were: (1) red meat, (2) processed and ultra-processed food, and (3) sugary and salty snacks. The choice set also contained items neither belonging to the healthy nor unhealthy food category and represented neutral items, used as our control items in subsequent analyses. The complete list of food items and their healthiness category can be found in the Supplementary material.

By conducting Bayesian generalized linear modeling, we investigate whether the PHS condition and its interaction with health categories and time (i.e., Session 2 or Session 3) affected the targeted outcome. Two main outcomes were the focus of our analyses: subjective food preferences, as measured by the food rating task, and food choices, as measured by the online shopping task. Depending on the outcome in focus, the models are either denoted as a Preference Model or Choice Model. In each model, the PHS condition (PHS-activated vs. PHS-deactivated), Session (Session 2 vs. Session 3), Healthiness of food items (healthy, neutral, and unhealthy), and the interaction between these factors were included as fixed effects. The intercept for all models was the healthy category, PHS-deactivated, Session 2. Further, three random effects were assumed: (1) a random intercept for the participants, (2) a random intercept for food items, and (3) a random slope for participants' hypnotizability on the PHS and Healthiness interaction (Model 1; Equation 1).

$$\begin{aligned} \textit{Model 1}: \textit{Outcome} \sim \textit{Session}{*}\textit{PHS}{*}\textit{Healthiness} + \left(1|\textit{Subjects}\right) \\ + \left(1|\textit{Food Items}\right) + \left(0 + \textit{PHS}{*}\textit{Healthiness}|\textit{Hypnotizability}\right) \quad (1) \end{aligned}$$

Three additional models were compared to the full model (Model 1) to gauge whether adding each factor improved the model's predictive capability: a model with only random intercepts (Model 4; Equation 4), a model with random intercepts and the fixed effect of Healthiness (Model 3; Equation 3), and a model with random intercepts and slope and the fixed effects of PHS and

Healthiness (Model 2; Equation 2).

$$Model\,2: \; Outcome \sim PHS{*}Healthiness + (1|Subjects) + (1\,|Food\ Items) + (0 + PHS{*}Healthiness|Hypnotizability) \quad (2)$$

$$Model\,3: \; Outcome \sim Healthiness + (1|\,Subjects) + (1\,|Food\ Items) \quad (3)$$

$$Model\,4: \; Outcome \sim 1 + (1|\,Subjects) \quad (4)$$

Further, when a significant behavioral result was observed, we tested the Bayesian equivalent of the robust correlation between the observed effects and the hypnotizability scores.

The results of the food rating and the online supermarket tasks were used to calculate logistic regression models (McKerchar et al., 2009; Scherbaum et al., 2012). For calculating these choice-preference functions, choices were entered into the model as binary input (i.e., yes = 1, no = 0) and subjective ratings as continuous predictors. The output of the model represents the probability of choosing an item, given the subjective rating for that item:

$$p_{j,i,k}(Y) = \frac{1}{1 + \exp^{(\beta_0 + \sum_i \beta_l x_l)}}, \quad (5)$$

where x designates subjective rating, Y choice, j participant number, i session, k food category, and β_0 and β_l are model parameters. The choice-preference functions were analyzed with the same approach used for assessing subjective ratings and food choices. The only difference is that subjective food ratings will always be used as a regressor in the models (from the baseline model to the full model). Further, the outcome will be a binary choice variable for each item, condition, and participant rather than the number of chosen items, which was used in Choice Models (Equation 6).

$$Choice_{Binary} \sim Preferences{*}Session{*}PHS{*}Healthiness + (1|Subjects) + (1\,|Food\ Items) + (0 + PHS{*}Healthiness|Hypnotizability) \quad (6)$$

All statistical analyses were conducted using the R programming language (http://www.R-project.org/). For calculating Bayesian hierarchical generalized linear models, brms (Bürkner, 2017) and RSTan (https://mc-stan.org/) were employed. The robust Bayesian correlations were calculated using RStan (https://mc-stan.org/). As all the models were multilevel, uninformative priors were preferred (Bürkner, 2017). Hence, we used $N(0, 2.5)$ as uninformative priors in the models for β coefficients, $student - t(3,\ 0,\ 2.5)$ for standard deviations, and $gamma(0.01,\ 0.01)$ for shape when necessary. Subjective food ratings, food choices, and choice-preference functions were modeled using cumulative, negative binomial, and logistic families, respectively. All models were calculated with ten chains, each having 5,000 iterations with 1,000 warmups. If any variable showed a *Rhat* (i.e., the potential scale reduction factor on split chains) above 1.05, the model was recalculated with increased iterations and reported accordingly. For the model comparison, we used the Pareto smoothed importance sampling (PSIS) estimation of leave-one-out cross-validation (loo) implemented in the loo package (Vehtari et al., 2016; Magnusson et al., 2020).

All hypotheses were tested using the hypothesis package from brms (Bürkner, 2017). Based on the suggestion of van Doorn et al. (2021), $Bayes\ factors(BF) > 3$ were considered as significant evidence for the tested hypothesis. One-sided hypotheses (BF_{+0} and BF_{0+}) were the comparison of the posterior probability of hypotheses against their alternative; two sided-tests (BF_{10} and BF_{01}) were the comparison between hypotheses and their alternative computed *via* the Savage-Dickey density ratio method.

3. Results

3.1. Subjective food preferences

First, to investigate the effectiveness of our PHS, we analyzed participants' subjective preferences (Figure 2A). The full Preference Model (Equation 1) tested the effect of PHS, Session, and Healthiness on subjective food ratings. The full Preference Model (Equation 1) had no divergent transition, all $Rhat = 1.00$, and all variables had bulk- and tail-effective sample sizes >2,000 and >5,000. Posterior checks showed that the cumulative count model simulations reasonably captured the features of the observed data, including distributions (Figure 2B), means of different conditions (Figure 2C), and dispersion (Figure 2D).

After confirming the validity of the Preference Model, the posteriors drawn from it were used to test our hypotheses (Figure 3). The results showed that activating PHS (PHS+) increased preferences for healthy food items ($H_+ : ConditionPHS > 0;\ mean = 0.39\,[0.28, 0.49],\ sd = 0.07, p.p. > 0.99, \mathbf{BF_{+0}} > \mathbf{9999}$). Further, activating PHS did not affect the preferences for neutral items ($H_0 : ConditionPHS + FoodItemHealthN : ConditionPHS = 0;\ mean = 0.06\,[-0.8, 0.19],\ sd = 0.08, p.p. = 0.97, \mathbf{BF_{01}} = \mathbf{33.65}$). Further, activating PHS probably decreased preferences for unhealthy items ($H_+ : ConditionPHS + FoodItemHealthU : ConditionPHS < 0;\ mean = -0.06\,[-0.16, 0.04],\ sd = 0.06, p.p. = 0.84, \mathbf{BF_{+0}} = \mathbf{5.19}$). Notably, although the results indicate that preferences for healthy food items were increased by PHS+, the evidence supporting a concomitant decrease in preferences for unhealthy food items is not strong. Given that zero is within the 95% confidence interval of alterations in unhealthy food preferences due to PHS, one should interpret this result with caution. Hence, although our results indicate that unhealthy food items' preferences were more likely ($p.p. = 0.83$) to be decreased rather than increased ($p.p. = 0.17$) due to PHS, one cannot rule out the possibility of no alterations.

Factor Session affected subjective food preference ratings neither as a main effect ($H_0 : SessionS3 = 0; mean = -0.06\,[-0.17, 0.05],\ sd = 0.05, p.p. = 0.96, \mathbf{BF_{01}} = \mathbf{25.12}$), nor in interaction with PHS ($H_0 : SessionS3 : ConditionPHS = 0; mean = -0.12\,[-0.27, 0.03],\ sd = 0.08, p.p. = 0.91, \mathbf{BF_{01}} = \mathbf{10.06}$), food category ($H_0 : SessionS3 : FoodItemHealthN + SessionS3 : FoodItemHealthU = 0;\ mean = 0.04\,[-0.21, 0.29],\ sd = 0.13, p.p. = 0.96, \mathbf{BF_{01}} = \mathbf{25.61}$), or in interaction with both PHS and food category ($H_0 : SessionS3 : ConditionPHS : FoodItemHealthN +$

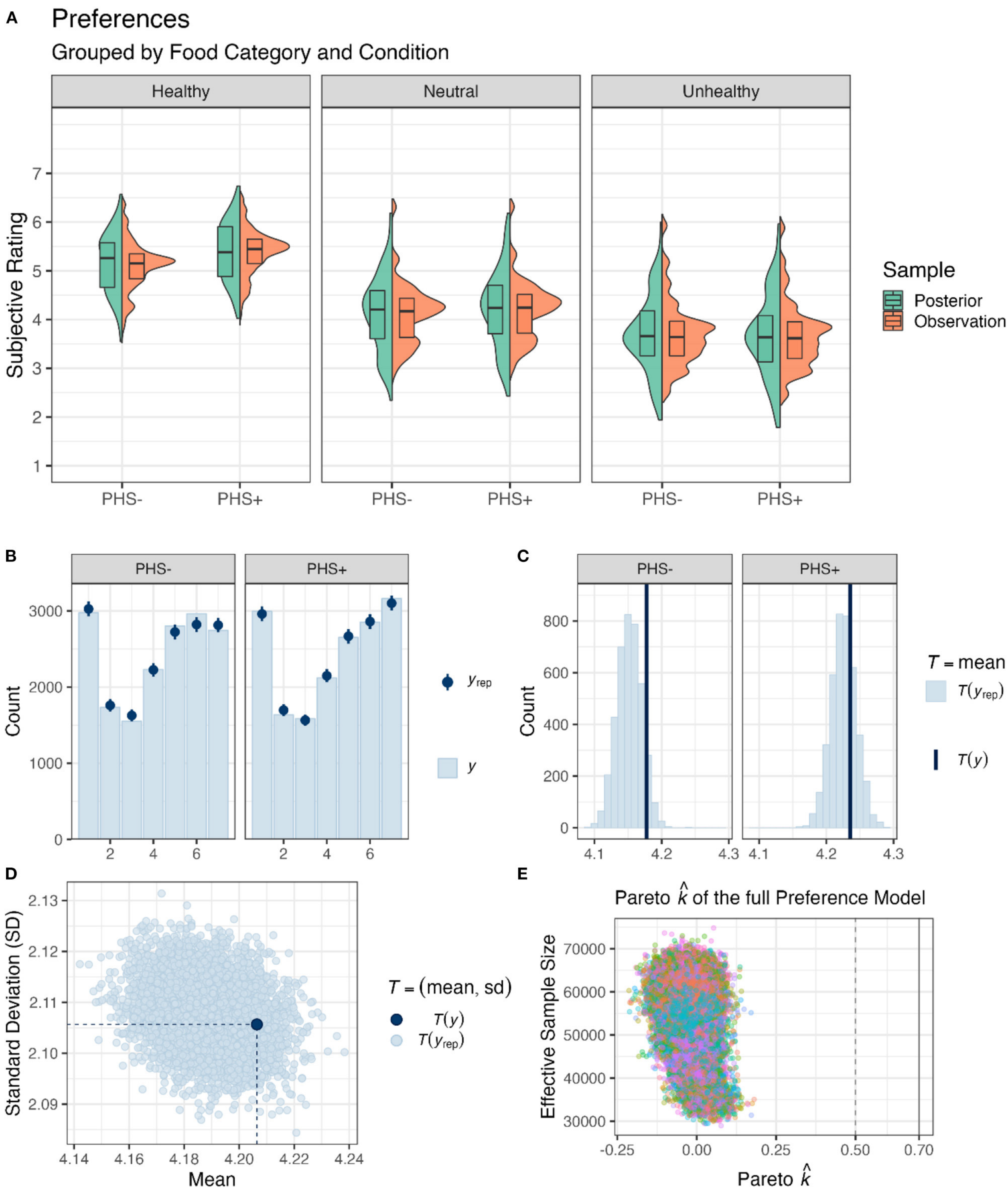

FIGURE 2
Food preferences. **(A)** Box and violin plots of the average preferences per participant for different food categories and PHS conditions pooled over Session. Green shapes depict observed data, and orange ones are from posterior distribution derived from the full Preference Model. **(B)** Means and standard error estimations, obtained from posterior distributions of preference ratings (y_{rep}) per level of the scale in both PHS conditions, are depicted by dark blue points and lines; light blue bars depict means of observed data (y). **(C)** Frequency density bar plots showing the estimated (y_{rep}) and observed mean preferences (y) in both PHS conditions. **(D)** A scatter plot showing the diffusion of subjective ratings. Light blue dots (y_{rep}) are estimated based on posterior distributions, and the dark blue dot (y) is the observed value. **(E)** Pareto $\hat{k}$ values for the full Prefences Model are depicted against the effective sample sizes for importance sampling.

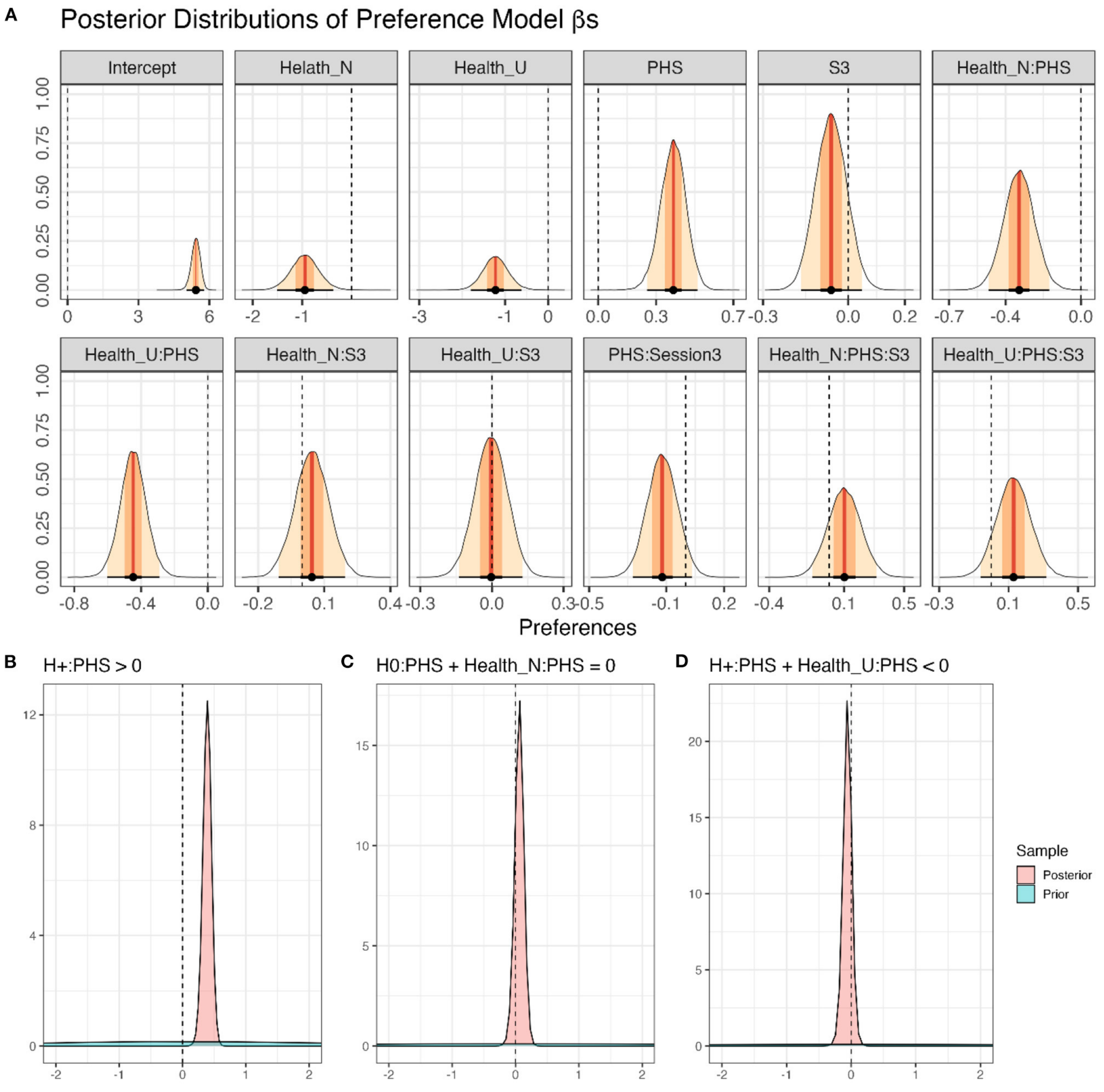

FIGURE 3
Modeling of food preferences. **(A)** Density plots of posterior distributions of all β-coefficients included in the full Preference Model (Model 1; Equation 1). The presented values are back-transformed from the cumulative logit scale. Red lines and orange and yellow shadows represent the mean point estimates and the 50 and 95% highest probability density (HPD) areas, respectively. Please note the different scalings of the X-axes. **(B–D)** The posterior distributions for specific a priori hypotheses. For more details regarding the hypotheses and results, see the text.

$SessionS3 : ConditionPHS : FoodItemHealthU = 0$; $mean = 0.23\,[-0.13, 0.59]$, $sd = 0.18$, $p.p. = 0.90$, $\mathbf{BF_{01}} = \mathbf{8.83}$).

Finally, healthy food items were preferred more than neutral items ($H_+ : FoodItemHealthN < 0$; $mean = -0.94\,[-1.41, -0.47]$, $sd = 0.29$, $p.p. > 0.99$, $\mathbf{BF_{+0}} = \mathbf{644.16}$), and more than unhealthy items ($H_+ : FoodItemHealthU < 0$; $mean = -1.22\,[-1.71, -0.73]$, $sd = 0.30$, $p.p. > 0.99$, $\mathbf{BF_{+0}} = \mathbf{3332.33}$). Also, neutral food items were probably preferred more than unhealthy items ($H_+ : FoodItemHealthU - FoodItemHealthN < 0$; $mean = -0.28\,[-0.78, 0.24]$, $sd = 0.31$, $p.p. = 0.82$, $\mathbf{BF_{+0}} = \mathbf{4.66}$).

In addition, we assessed which fixed effect would enhance the predictive capability of the suggested model using PSIS-loo estimations. To check whether PSIS-loo estimations of the compared models are reliable, the full Preference Model *Pareto* $\hat{k}$ values were calculated (Figure 2E). All values were below the suggested (Vehtari et al., 2016; Magnusson et al., 2020) threshold of *Pareto* $\hat{k} < 0.7$, ascertaining that the comparison can be trusted. PSIS-loo criteria showed that the addition of PHS

TABLE 1 Fit indices of the preference models computed by multilevel Bayesian cumulative modeling (ordered by fit).

Preference model	$\widehat{elpd}_{diff}$	$se(\widehat{elpd}_{diff})$	$\widehat{elpd}_{loo}$	$se(\widehat{elpd}_{loo})$
Model 1: *Session∗PHS∗ Healthiness +RE*	0.0	0.0	−58558.7	119.4
Model 2: **PHS∗Healthiness+ RE**	−2.4	4.1	−58561.1	119.3
Model 3: *Healthiness + RE*	−279.1	26.0	−58837.8	117.6
Model 4: 1 + *RE*	−5307.6	97.0	−63866.3	70.8

The endorsed model is indicated in bold. All models are compared to the best model (i.e., Model 1). More complex models are considered to be better if they show more than one standard error enhancement in $\widehat{elpd}_{diff}$ (Vehtari et al., 2016; Magnusson et al., 2020). RE, Random effects. For a detailed specification of the models, see Equations (1)–(4). $\widehat{elpd}_{loo}$, Expected log pointwise predictive density for a new dataset using the Pareto smoothed importance sampling (PSIS) leave-one-out cross-validation (loo) criterion (Vehtari et al., 2016; Magnusson et al., 2020). The closer to zero, the better the model is. $\widehat{elpd}_{diff}$, The difference between $\widehat{elpd}_{loo}$ of two compared models. se, Standard error of the targeted variable.

and Healthiness would enhance model performance. Although adding Session enhanced PSIS-loo (Table 1), the improvement was below the standard error. Therefore, Preference Model 2 was preferred over the others. This outcome corroborates the results obtained from the full Preference Model, demonstrating that Session and its interactions with Healthiness or PHS did not affect food preferences.

3.2. Online supermarket task

To understand the effects of PHS, Session, and Healthiness on food choices in a realistic shopping simulation, we analyzed the results of the online supermarket task (Figure 4A) by applying the models specified in the Section 2.4. Data analysis. Notably, in the choice models, the number of chosen items per food item (i.e., a discrete-continuous variable) was used as the outcome. The full Choice Model (Equation 1) showed no divergent transition, all $Rhat = 1.00$, and all variables had bulk- and tail-effective sample sizes >2,000 and >5,000. Posterior checks showed that the negative binomial model simulations reasonably capture the features of the observed data, including distributions (Figure 4B), means of conditions (Figure 4C), and dispersion (Figure 4D).

After confirming the validity of the full Choice Model, the posteriors drawn from it were used to test our hypotheses (Figure 5). The results show that PHS increased choices of healthy food items ($H_+ : ConditionPHS > 0$; $mean = 0.11\,[0.02, 0.19]$, $sd = 0.05, p.p. = 0.98, \mathbf{BF_{+0} = 49.70}$). In contrast, PHS did not affect the choices of neutral items ($H_0 : ConditionPHS + FoodItemHealthN : ConditionPHS = 0$; $mean = -0.05\,[-0.19, 0.08]$, $sd = 0.07, p.p. = 0.98, \mathbf{BF_{01} = 39.57}$). Finally, PHS probably decreased choices of unhealthy food items ($H_+ : ConditionPHS + FoodItemHealthU : ConditionPHS < 0$; $mean = -0.13\,[-0.35, 0.09]$, $sd = 0.14, p.p. = 0.85, \mathbf{BF_{+0} = 5.56}$). Similar to preference ratings, even though the results indicated that choices of healthy food items were increased by PHS, the evidence supporting the decrease in choices of unhealthy food items by PHS was not strong. Given that zero is included in the 95% confidence interval of the change in unhealthy food choices due to PHS, one should interpret this result with caution. That is, although this result indicates that choices for unhealthy food items were more likely ($p.p. = 0.85$) to decrease rather than increase ($p.p. = 0.15$) due to PHS, one should not rule out the possibility of no modulation.

As for preferences, Session did not affect food choice behavior, neither as a main effect ($H_0 : SessionS3 = 0; mean = -0.07\,[-0.16, 0.01]$, $sd = 0.04, p.p. = 0.94, \mathbf{BF_{01} = 14.42}$), nor in interaction with PHS ($H_0 : SessionS3 : ConditionPHS = 0$; $mean = 0.03\,[-0.09, 0.15]$, $sd = 0.06, p.p. = 0.97, \mathbf{BF_{01} = 36.02}$), food category ($H_0 : SessionS3 : FoodItemHealthN + SessionS3 : FoodItemHealthU = 0$; $mean = 0.13\,[-0.12, 0.37]$, $sd = 0.12, p.p. = 0.94, \mathbf{BF_{01} = 16.76}$), or in interaction with both factors ($H_0 : SessionS3 : ConditionPHS : FoodItemHealthN + SessionS3 : ConditionPHS : FoodItemHealthU = 0$; $mean = -0.13\,[-0.48, 0.22]$, $sd = 0.18, p.p. = 0.94, \mathbf{BF_{01} = 15.71}$).

Finally, healthy food items were chosen more often than both neutral items ($H_+ : FoodItemHealthN < 0$; $mean = -0.70\,[-1.10, -0.30]$, $sd = 0.24, p.p. > 0.99, \mathbf{BF_{+0} = 299.75}$), and unhealthy items ($H_+ : FoodItemHealthU < 0$; $mean = -1.56\,[-1.94, -1.19]$, $sd = 0.23, p.p. > 0.99, \mathbf{BF_{+0} > 9999}$). Also, neutral food items were chosen more often than unhealthy ones ($H_+ : FoodItemHealthU - FoodItemHealthN < 0$; $mean = -0.87\,[-1.20, -0.53]$, $sd = 0.20, p.p. > 0.99, \mathbf{BF_{+0} > 9999}$).

Additionally, we assessed which fixed effect would enhance the predictive capability of the suggested model using PSIS-loo estimations. To check whether PSIS-loo estimations of the compared models are reliable, the full Choice Model $Pareto\ \hat{k}$ values were calculated (Figure 4E). All values were below the suggested (Vehtari et al., 2016; Magnusson et al., 2020) threshold of $Pareto\ \hat{k} < 0.7$, indicating that the comparison can be trusted. PSIS-loo criteria showed that adding PHS and Healthiness enhanced the model performance. However, adding Session deteriorated PSIS-loo (Table 2). Therefore, Choice Model 2 was considered the preferred model. This outcome corroborates the results obtained from the full Choice Model, showing that Session and its interactions did not affect food choices.

3.3. Choice-preference function

After analyzing the online supermarket and subjective rating tasks separately, we addressed whether the relationship between choice behavior and preferences was modulated by PHS, Session, and Healthiness of the food items. For this purpose, the choice-preference function was calculated (logistic regression hierarchical Bayesian models), where binary choices were modeled by using preferences as a regressor (Figure 6A). The full Choice-Preference Function (Equation 6) showed no divergent transitions, all $Rhat = 1.00$, and all variables had bulk- and tail-effective sample sizes >3,000 and >6,000. Posterior checks showed that the logistic model simulations reasonably captured the features of the observed

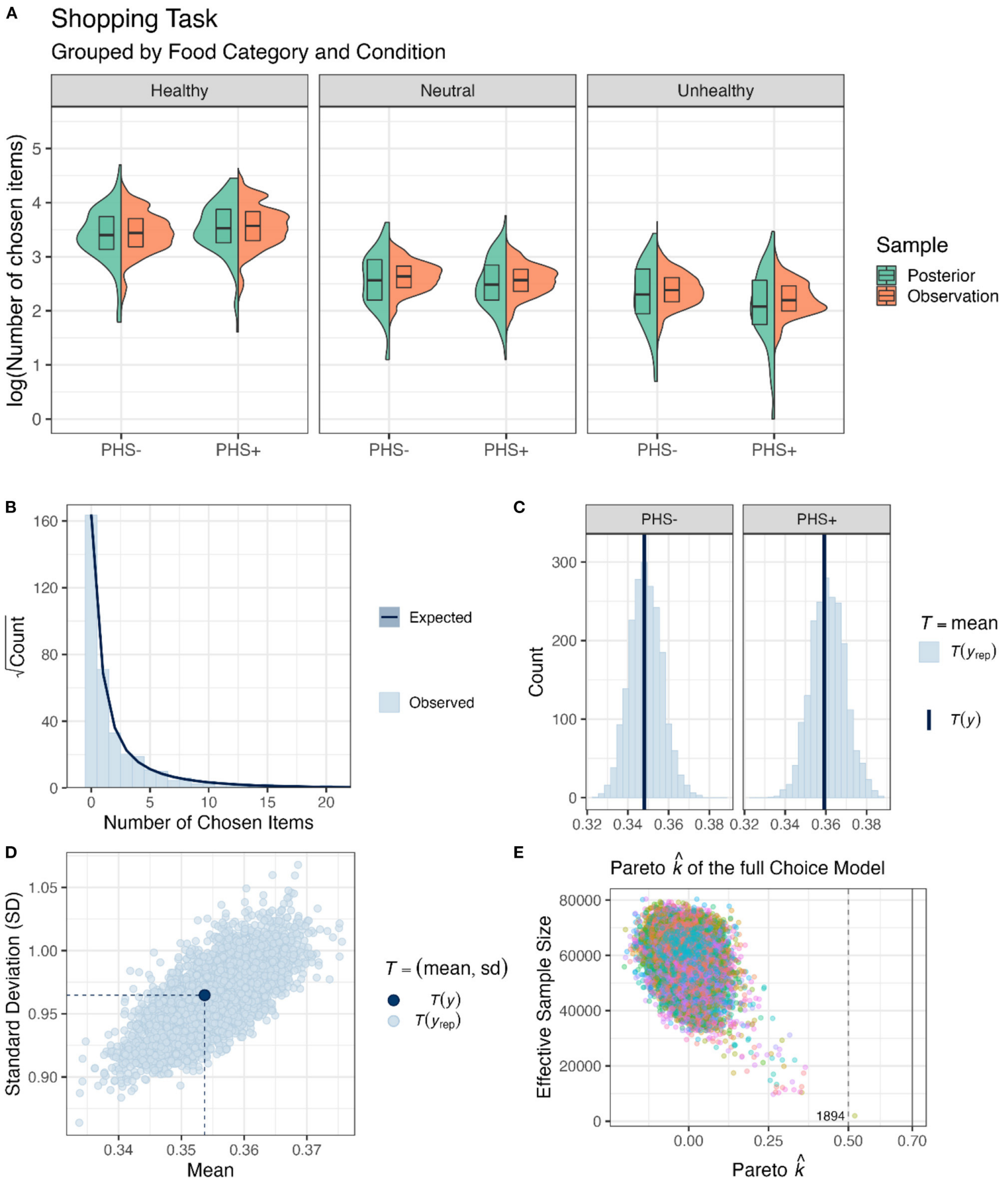

FIGURE 4
Food choice behavior in the online supermarket task. **(A)** Box and violin plots of the average sum of chosen items per participant, food category, and PHS condition on the log scale (pooled over Session). Note that the data was curated for plotting purposes, as first, the choices were averaged for each health category and participant, and then the log of these values was plotted here. **(B)** A bar plot of the data obtained from the shopping task depicting the distribution of the observations. The dark blue line and shadows represent mean and standard error estimates obtained from posterior distributions. **(C)** Frequency density bar plots showing the estimated (y_{rep}) and observed mean numbers of items chosen (y) in the two PHS conditions. **(D)** A scatter plot showing the diffusion of choices. Light blue dots (y_{rep}) are estimated based on posterior distributions, and the dark blue dot (y) is the observed value. **(E)** Pareto $\hat{k}$ values for the full Choice Model are depicted against the effective sample sizes for importance sampling. If leaving out an observation changes the posterior too much, then PSIS-loo is not able to give a reliable estimate (Vehtari et al., 2016; Magnusson et al., 2020). However, in the current model and sample, there was no value over 0.7 and only one value over 0.5, which is annotated with the pseudo-ID.

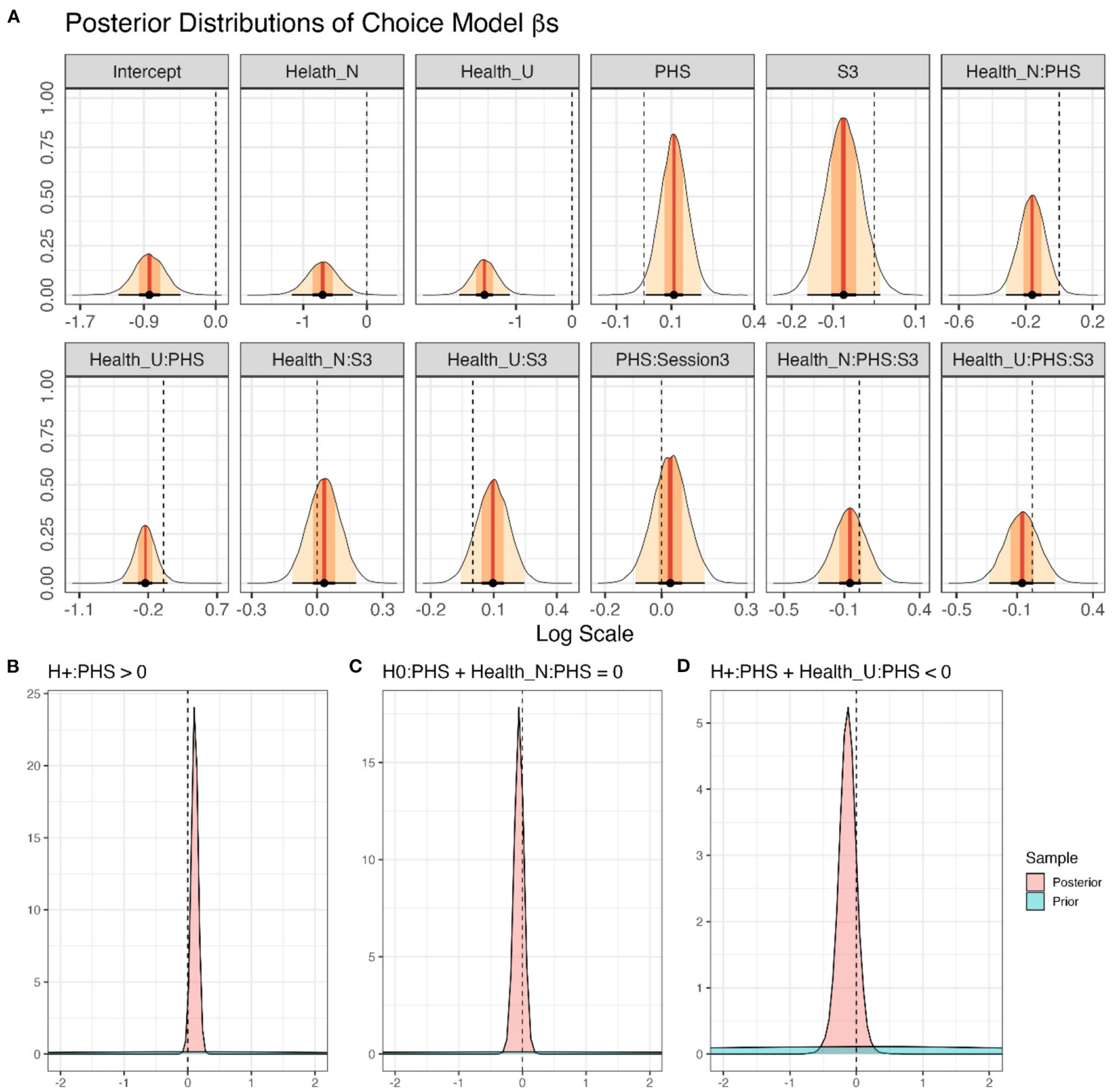

FIGURE 5
Modeling of choice performance in the online supermarket task. **(A)** Density plots of posterior distributions of all β-coefficients included in the full Choice Model (Equation 1); presented values are in log scale. Red lines and orange and yellow shadows represent the mean point estimates and the 50 and 95% highest probability density (HPD) areas, respectively. Please note the different scalings of the X-axes. **(B–D)** The posterior distributions for specific a priori hypotheses. For more details regarding the hypotheses and results, see the text.

data, including distributions (Figure 6C) and means of different conditions (Figure 6D).

After confirming the validity of the full Choice-Preference Function, the posteriors drawn from it were used to test our hypotheses (Figure 7A). Two sets of results are presented; the first set is related to the interaction of the experimental factors with preferences, which are associated with the modulation of slopes of the *Choice* ∼ *Preference* relationship (Figure 6B). These results indicate the importance of preferences in choice behavior. The second set is related to the effects of the experimental factors on choices regardless of preferences, which is represented by the intercepts of the *Choice* ∼ *Preference* relationship (Figure 6B). These results reveal general biases toward choosing items of a certain category in different conditions, regardless of preferences.

First, we focused on the effects of preferences on choice behavior in the different food categories (Figure 7B). For healthy items, increased preferences positively affected choices ($H_{+}: Preferences > 0$; $mean = 1.01\,[0.93, 1.09]$, $sd = 0.05$, $p.p. > 0.99$, $\mathbf{BF_{+0}} > \mathbf{9999}$). The relationship between preferences and choices was indistinguishable between the neutral and healthy

TABLE 2 Fit indices of the choice models computed by multilevel Bayesian generalized linear modeling (ordered by fit).

Choice model	$\widehat{elpd}_{diff}$	$se(\widehat{elpd}_{diff})$	$\widehat{elpd}_{loo}$	$se(\widehat{elpd}_{loo})$
Model 2: **PHS∗Healthiness +RE**	0.0	0.0	−20476.4	174.2
Model 1: *Session∗PHS∗ Healthiness + RE*	−3.8	2.5	−20480.2	174.3
Model 3: *Healthiness + RE*	−79.9	5.8	−20556.2	174.3
Model 4: 1 + *RE*	−4754.3	100.2	−25230.6	208.0

The endorsed model is indicated in bold. All models are compared to the best model (i.e., Model 2). More complex models are considered to be better if they show more than one standard error enhancement in $\widehat{elpd}_{diff}$ (Vehtari et al., 2016; Magnusson et al., 2020). RE, Random effects. For a detailed specification of the models, see Equations (1)–(4). $\widehat{elpd}_{loo}$, Expected log pointwise predictive density for a new dataset using the Pareto smoothed importance sampling (PSIS) leave-one-out cross-validation (loo) criterion (Vehtari et al., 2016; Magnusson et al., 2020). The closer to zero, the better the model is. $\widehat{elpd}_{diff}$, The difference between $\widehat{elpd}_{loo}$ of two compared models. se, Standard error of the targeted variable.

food categories ($H_0 : Preferences : FoodItemHealthN = 0$; $mean = 0.02\,[-0.11, 0.16]$, $sd = 0.07$, $p.p. = 0.97$, $\mathbf{BF_{01}= 34.35}$. Interestingly, the importance of preferences in choice behavior was less pronounced for unhealthy compared to healthy food items ($H_+ : Preferences : FoodItemHealthU < 0$; $mean = -0.14\,[-0.24, -0.03]$, $sd = 0.06$, $p.p. = 0.98$, $\mathbf{BF_{+0}= 61.31}$).

Further, participants were more likely to show a negative bias (i.e., diminished choice behavior regardless of preferences) for both neutral ($H_+ : FoodItemHealthN < 0$; $mean = -0.51\,[-1.23, 0.21]$, $sd = 0.44$, $p.p. = 0.88$, $\mathbf{BF_{+0}= 7.18}$) and unhealthy items ($H_+ : FoodItemHealthU < 0$; $mean = -0.51\,[-1.18, 0.16]$, $sd = 0.41$, $p.p. = 0.88$, $\mathbf{BF_{+0}= 8.32}$) as compared to healthy food items. However, there was no difference in choice bias for unhealthy compared to neutral items ($H_0 : FoodItemHealthU - FoodItemHealthN = 0$; $mean = 0.0\,[-0.81, 0.80]$, $sd = 0.42$, $p.p. = 0.89$, $\mathbf{BF_{01}= 8.23}$).

Second, we addressed whether PHS had altered the relationship between choice behavior and preferences (i.e., slopes) for the different food categories. Notably, PHS did not affect the relationship between choices and preferences for both healthy items ($H_0 : Preferences : ConditionPHS = 0$; $mean = -0.10\,[-0.23, 0.03]$, $sd = 0.07$, $p.p. = 0.92$, $\mathbf{BF_{01}= 11.24}$) as well as neutral items ($H_0 : Preferences : ConditionPHS + Preferences : FoodItemHealthN : ConditionPHS = 0$; $mean = -0.07\,[-0.21, 0.06]$, $sd = 0.07$, $p.p. = 0.97$, $\mathbf{BF_{01}= 28.43}$). In contrast, unhealthy items were more likely to be affected by preferences when PHS was activated compared to deactivated ($H_+ : Preferences : ConditionPHS + Preferences : FoodItemHealthU : ConditionPHS > 0$; $mean = 0.21\,[0.10, 0.32]$, $sd = 0.07$, $p.p. > 0.99$, $\mathbf{BF_{+0}= 1110.11}$).

Also, when considering choice biases (i.e., intercepts), PHS+ compared to PHS- did not affect choice bias for healthy ($H_0 : ConditionPHS = 0$; $mean = 0.51\,[-0.29, 1.31]$, $sd = 0.41$, $p.p. = 0.92$, $\mathbf{BF_{01}= 11.24}$) or neutral items ($H_0 : ConditionPHS + FoodItemHealthN : ConditionPHS = 0$; $mean = -0.07\,[-0.21, 0.06]$, $sd = 0.07$, $p.p. = 0.97$, $\mathbf{BF_{01}= 28.43}$). In contrast, PHS+ induced a negative bias for unhealthy items compared to PHS- ($H_+ : ConditionPHS + FoodItemHealthU : ConditionPHS < 0$; $mean = -1.37\,[-2.10, -0.65]$, $sd = 0.44$, $p.p. > 0.99$, $\mathbf{BF_{+0}= 753.72}$).

Together, the results indicate that PHS affected the relationship between preferences and choices only for unhealthy food items (Figure 7B). These effects, however, are two-fold. PHS caused participants to reject unhealthy items more frequently regardless of preferences (i.e., a negative choice bias). Simultaneously, PHS made preferences more critical in participants' unhealthy choices (Figure 7B).

Finally, we checked which fixed effect would enhance the predictive capability of the suggested model using PSIS-loo estimations. To check whether PSIS-loo estimations of the compared models are reliable, the full Choice-Preference Function *Pareto* $\hat{k}$ values were calculated. All values were below the suggested (Vehtari et al., 2016; Magnusson et al., 2020) threshold (i.e., *Pareto* $\hat{k} < 0.7$), ascertaining that the comparison can be trusted. PSIS-loo criteria showed that the addition of PHS and Healthiness enhanced model performance. However, adding Session deteriorated PSIS-loo (Table 3). Therefore, the Choice-Preference Function 2 was considered the preferred model, suggesting that Session and its interactions did not affect choice-preference relationships.

3.4. Hypnotizability

Two approaches were used to address whether hypnotizability scores predict changes in subjective ratings and choice behavior. First, the full models (Equation 1) were compared with models that did not contain random slopes but were otherwise identical to the full model. Second, a robust Bayesian correlation test was conducted to understand whether the changes in healthy, neutral, or unhealthy categories due to PHS were correlated with hypnotizability scores.

Regarding subjective preferences, the model without random slope was significantly worse than the full model ($\widehat{elpd}_{diff} = -237.4$, $se(\widehat{elpd}_{diff}) = 24.1$, $\mathbf{BF_{10}> 999}$), showing that hypnotizability scores are crucial for predicting participants' preferences. Further, the robust correlation test corroborated this result (Figures 8A–C), revealing that changes in preferences for healthy ($\rho_{mean} = 0.232\ [\,0.030,\ 0.423]$, $sd = 0.100$, $\mathbf{p.p_{\rho>0}= 0.98}$) and unhealthy items ($\rho_{mean} = -0.202\ [\,-0.400,\ -0.010]$, $sd = 0.100$, $\mathbf{p.p_{\rho<0}= 0.97}$) were correlated with hypnotizability scores positively and negatively, respectively. However, the changes in preferences for the neutral food category were not significantly correlated with hypnotizability ($\rho_{mean} = +0.148\ [\,-0.058,\ 0.347]$, $sd = 0.104$, $p.p_{\rho>0} = 0.88$).

Also, regarding choice behavior in the shopping task, the model without random slope was significantly worse than the full model ($\widehat{elpd}_{diff} = -66.4$, $se(\widehat{elpd}_{diff}) = 12.8$, $\mathbf{BF_{10}> 999}$), showing that hypnotizability is crucial for predicting participants' choices. Additionally, the robust correlation test corroborated this result (Figures 8D–F), revealing that changes in choosing healthy ($\rho_{mean} = 0.520\ [0.358,\ 0.677]$, $sd = 0.081$, $\mathbf{p.p_{\rho>0}> 0.99}$)

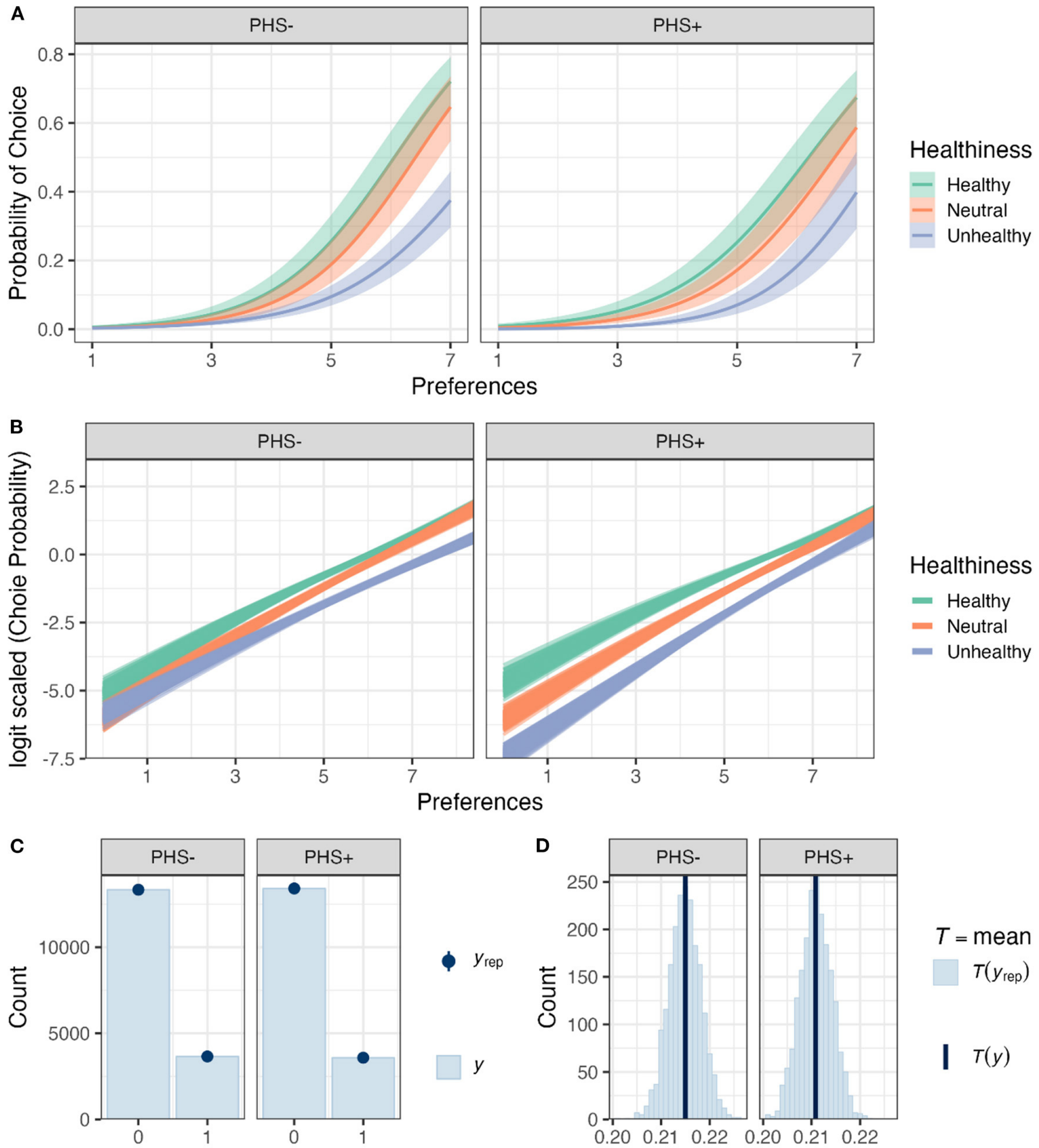

FIGURE 6
The relationship of food preferences and choice behavior in the supermarket task. **(A)** Choice probabilities as a function of preferences based on model predictions for different food categories and PHS conditions. Solid lines and shadows represent means and standard errors based on posterior distributions, respectively. **(B)** Choice probabilities in logit scale as a function of preferences based on model predictions for different food categories and PHS conditions. In total, 200 lines are shown for each condition, where each line presents a posterior prediction. **(C)** A bar plot (y) of the data obtained from the choice behavior (i.e., the model's outcome) depicting the distribution of the observations. The blue dots and lines (y_{rep}) represent mean and standard error estimates obtained from posterior distributions of the full Choice-Preference Function. **(D)** Frequency density bar plots showing the estimated (y_{rep}) and observed mean choice behavior (y) in the two PHS conditions.

and unhealthy items ($\rho_{mean} = -0.444$ $[-0.620, -0.272]$, $sd = 0.090$, $\mathbf{p.p}_{\rho<0}$= **0.99**) were correlated positively and negatively with hypnotizability, respectively. However, the changes in neutral food category choices were not significantly correlated with hypnotizability ($\rho_{mean} = 0.033$ $[-0.182, 0.243]$, $sd = 0.109$, $p.p_{\rho>0} = 0.62$).

Finally, for the choice-preference function, we compared the full models (Equation 6) with models without random slopes but otherwise identical to the full model. The model without random slope was significantly worse than the full model ($\widehat{elpd}_{diff} = -23.9$, $se(\widehat{elpd}_{diff}) = 7.1$, $\mathbf{BF_{10}} > \mathbf{999}$), revealing that hypnotizability scores are crucial for predicting the choice-preference function. Notably, as slopes and choice biases derived from the choice-preference function were the prediction of the Bayesian logistic model, using them for modeling the robust Bayesian correlation might

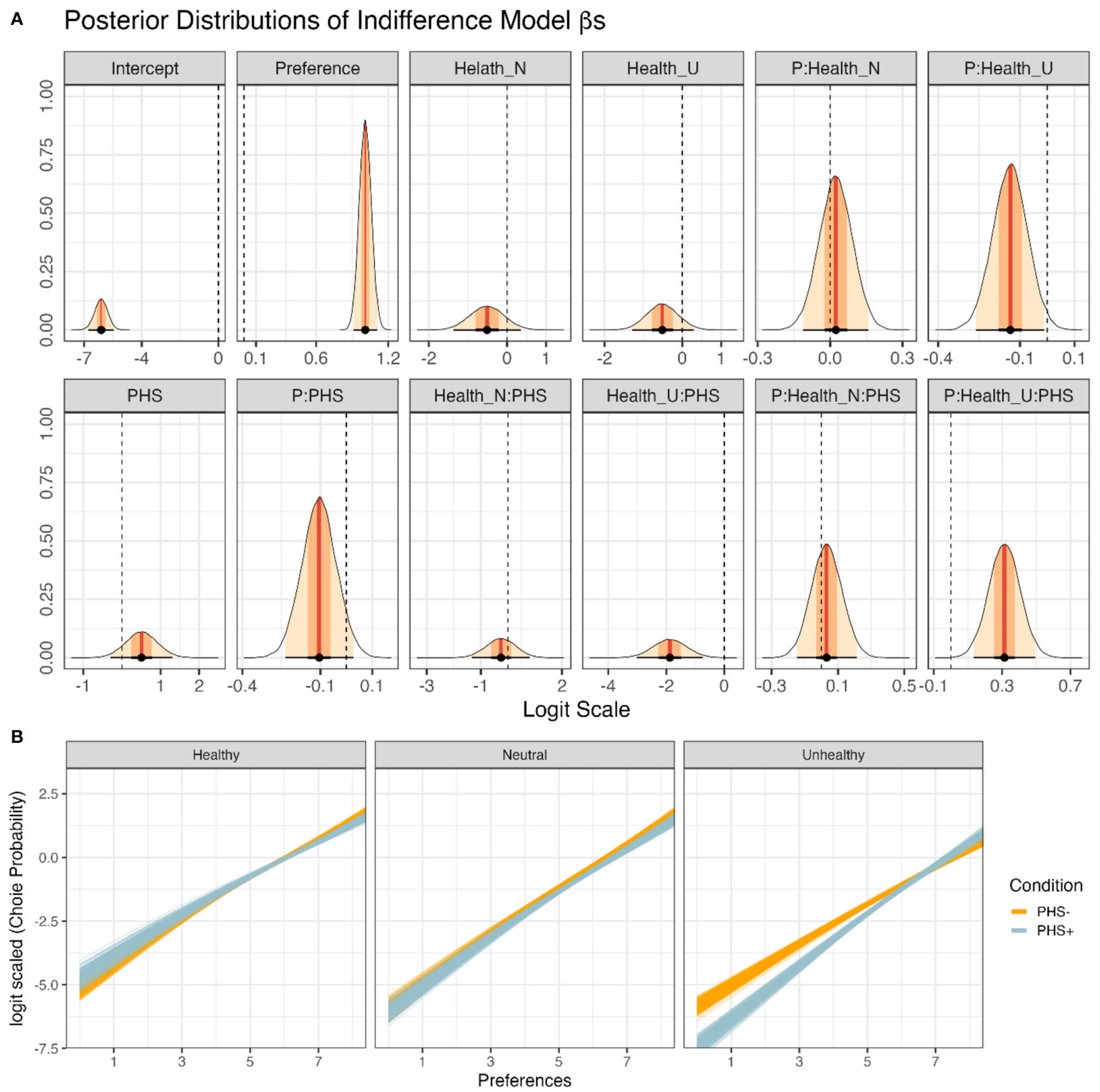

FIGURE 7
Modeling of the relationship between choices, as measured by the online supermarket task, and preferences, as measured by the subjective rating task. **(A)** Posterior distributions of all β-coefficients included in the full Preference Model, except those containing Session or its interactions (Equation 6). Red lines and orange and yellow shadows represent the mean point estimates and the 50 and 95% highest probability density (HPD) areas, respectively. Please note the different scalings of the X-axes. **(B)** The posterior predictions for specific hypotheses. For more details regarding the hypotheses and results, see the text. Each line presents a posterior prediction; in total, 200 predictions are shown.

have been misleading; therefore, we refrained from using this approach.

4. Discussion

To address the effects of PHSs on food preferences and choices, we conducted an online-only, repeated-measures study with three sessions. In the first session, participants' hypnotizability was measured using HGSHS. Notably, all participants were included in the sample regardless of their hypnotizability. At the beginning of Session 2, participants received hypnosis, including a PHS aiming to increase preferences for healthy food items. Following the hypnosis, they took part in our task set twice, once when the PHS was activated and once when it was deactivated. The task set consisted of a subjective rating task, measuring participants' explicit preferences for a large number of diverse food items, and a realistic shopping simulation, measuring participants' choice

TABLE 3 Fit indices of the choice-preference functions computed by multilevel Bayesian logistic regression linear modeling (ordered by fit).

Choice-preference function	$\widehat{elpd}_{diff}$	$se(\widehat{elpd}_{diff})$	$\widehat{elpd}_{loo}$	$se(\widehat{elpd}_{loo})$
Model 2: **Preferences∗PHS∗ Healthiness+RE**	0.0	0.0	−10600.2	101.2
Model 1: *Preferences∗Session∗ PHS∗Healthiness+ RE*	−2.1	4.6	−10602.3	101.3
Model 3: *Preferences∗ Healthiness + RE*	−44.5	10.3	−10644.8	102.2
Model 4: *Preferences + RE*	−1574.4	55.3	−12174.7	100.3

The endorsed model is indicated in bold. All models are compared to the best model (i.e., Model 2). More complex models are considered to be better if they show more than one standard error enhancement in $\widehat{elpd}_{diff}$ (Vehtari et al., 2016; Magnusson et al., 2020). RE, Random effects. For a detailed specification of the models, see Equations (1)–(4). $\widehat{elpd}_{loo}$: Expected log pointwise predictive density for a new dataset using the Pareto smoothed importance sampling (PSIS) leave-one-out cross-validation (loo) criterion (Vehtari et al., 2016; Magnusson et al., 2020). The closer to zero, the better the model is. $\widehat{elpd}_{diff}$, The difference between $\widehat{elpd}_{loo}$, of two compared models. se, Standard error of the targeted variable.

behavior for the same items. Session 3 mimicked Session 2 but did not repeat hypnosis and PHS instructions but merely activated and deactivated the PHS introduced in Session 2.

The results of the rating task revealed that the PHS increased preferences for healthy food items. These results are in line with previous reports, showing that PHSs can successfully alter food preferences (Ludwig et al., 2014; Zahedi et al., 2020a). Notably, the results of our online supermarket task revealed that the increase in explicit preferences for healthy items was accompanied by increased choices in a realistic shopping scenario. This finding is of great importance when considering the prevalence of obesity in industrialized societies (Swinburn et al., 1999; Jaacks et al., 2019) and the inability of traditional approaches, such as diet control and cognitive training, to change patterns of food consumption (for review, see Stephens et al., 2014; Yang et al., 2019).

The choice-preference function analysis showed that although the PHS affected food preferences and choices of healthy items, the relationship between preferences and choices was not altered. In other words, one may reasonably suggest that changes in choice behavior in favor of healthy items were driven by increased preferences for these types of food. As Ainslie (2020) discussed, this form of choice modulation, called resolve, can be distinguished from changes in choice behavior by means of suppressing unaltered preferences. Although resolve is a subcomponent of inhibition, a well-investigated executive function (Miyake et al., 2000; Miyake and Friedman, 2012; Diamond, 2013; Yuan and Raz, 2014; Limbers and Young, 2015), there is an ongoing debate about the efforts involved in its implementation (Ainslie, 2020). Considering an example clarifies this point. If someone has a strong preference for food item A but should not or does not want to consume it for any reason, there are two options to change their behavior: suppression and resolve. Suppression refers to refraining from consuming food item A, even though it is preferred, which requires constant effort.

In contrast, resolve refers to following an alternative, possibly preconceived plan for selecting an alternative food item B. One reasonable strategy is to associate food Item B with positive rewards and item B with negative concepts, or in other words, attenuate the comparative subjective value of item A. As argued by Ainslie (2020), suppression is effortful, while resolve may not be. Certainly, it will be highly valuable to address the required efforts in inhibition involving mere suppression vs. inhibition relying on resolve.

Notably, a number of studies have shown that (post-)hypnotic suggestions are implemented through top-down modulations (Terhune et al., 2017), require attention allocation (Tobis and Kihlstrom, 2010), and require cognitive effort (Parris et al., 2021). Further, the relationship between food-related PHSs and executive functions (requiring cognitive effort) has also been demonstrated (Ludwig et al., 2014; Zahedi et al., 2020a). Combining our current results with previous findings regarding the effortfulness of PHS effects (Tobis and Kihlstrom, 2010; Zahedi et al., 2017, 2019, 2020a), we tentatively suggest that resolve, like its sibling suppression, might be effortful at the time of implementation (Zahedi et al., 2020a). However, unlike suppression, resolve leads to long-term changes in choice behavior through modulation of preferences that may be implemented effortlessly (Ainslie, 2020). One should note that these interpretations are speculative and require further investigations.

The PHS not only increased the preference for healthy items but also decreased preferences and choices of unhealthy food items. For unhealthy items, the choice-preference function analysis revealed that—in contrast to healthy and neutral items—the PHS altered the relationship between food choices and preferences. The effects were two-fold. First, the PHS induced a negative choice bias for unhealthy items, meaning when disregarding the effects of preferences, participants were less likely to choose unhealthy items when the PHS was activated. However, food preferences became more critical in unhealthy choices when the PHS was activated compared to the deactivated condition. When interpreting these results, one should consider two points. (I) As the current study's PHS (Appendix A) focuses on healthy items, one might suggest that changes in other food categories, such as unhealthy items, indicate demand characteristics rather than genuine modulation of choice behavior. Bayesian statistics (van Doorn et al., 2021) showed that for neutral food items, neither separately analyzed preferences and choices nor the relationship between them were affected by the PHS. If participants were responding to demand characteristics (e.g., being positively biased toward healthy items), one should also expect a decrease in the preferences and choices of neutral items. Therefore, the changes in choices of unhealthy food items are hard to explain in terms of demand characteristics. (II) Food preferences are not the only factor affecting food choices. Other factors, such as impulsivity (Guerrieri et al., 2008; Wiers et al., 2011; Jones et al., 2018) and transitory states like hunger or stress (Nederkoorn et al., 2009; Froehlich et al., 2021a,b), can strongly affect food choices. Therefore, a plausible explanation for the changes observed regarding unhealthy food items is that under the effects of the PHS, participants were more thoughtful regarding unhealthy choices, with the consequence of suppressing these choice options more frequently.

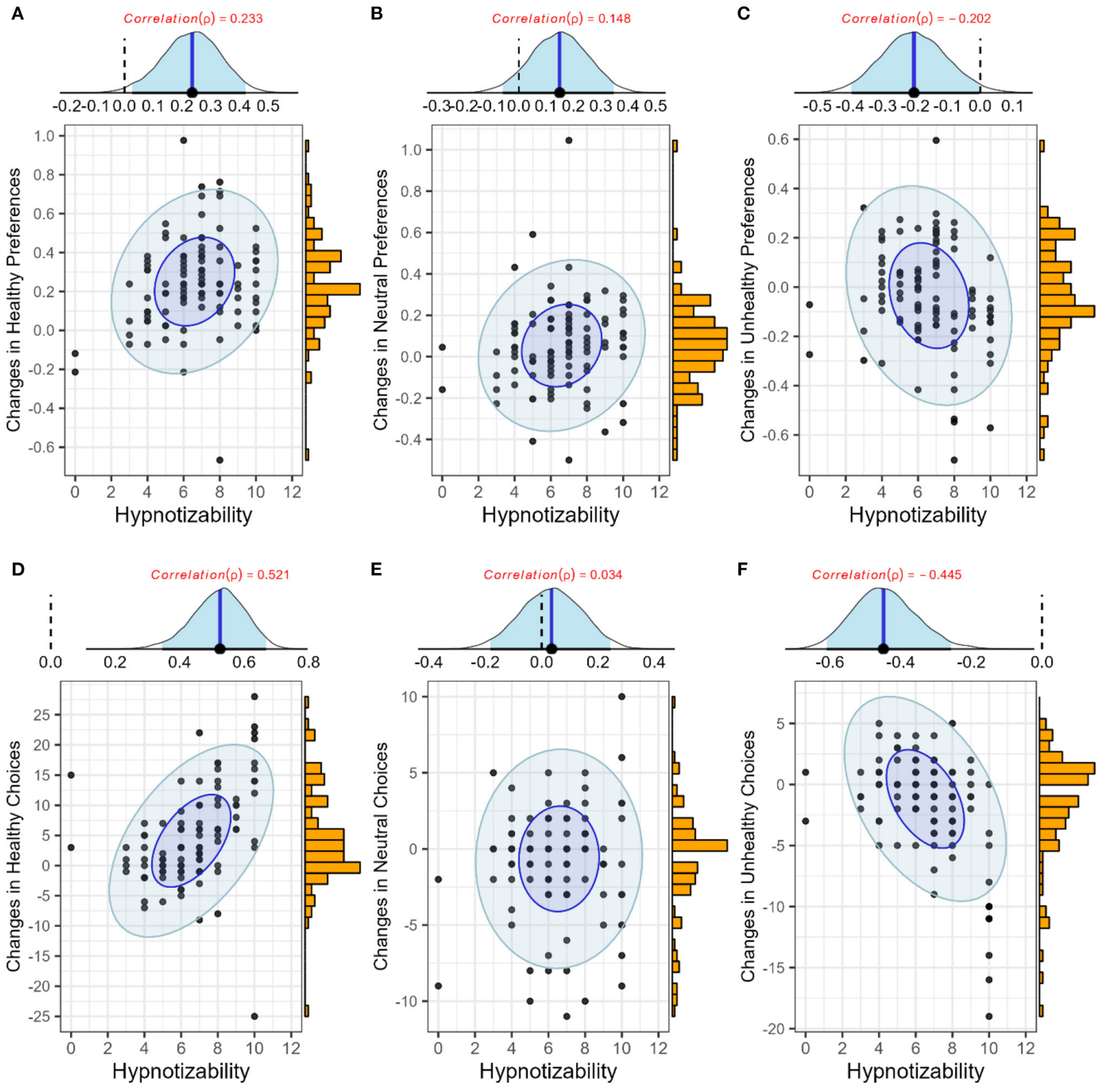

FIGURE 8
Effects of hypnotizability on Food Preferences (top) and Food Choice (bottom). Each panel shows three elements. (Top) The posterior distribution of ρ (blue lines and shadows show means and 95% highest density intervals); (right) a histogram of changes in the targeted variable drawn from observations; and (mid) point and eclipse plots, representing the observations and robust posterior predictions, respectively. Dark blue and light blue ellipses show the 50 and 95% highest density areas. **(A–C)** Changes in preferences for healthy, neutral, and unhealthy items; **(D–F)** Changes in choices of healthy, neutral, and unhealthy items.

The deliberate decision-making strategy employed by participants regarding unhealthy food items can be contrasted with being impulsive (Pereira et al., 2005; Navarro-Allende et al., 2008; Kakoschke et al., 2017; Jones et al., 2018). Additionally, however, it should be contrasted to the changes in healthy food choices, which may be accounted for by implementing "resolve." Specifically, since previous findings showed that participants are better at inhibiting temptations by unhealthy food under the effects of PHSs (Zahedi et al., 2020a), this interpretation seems even more justified. Given that in the obesogenic environments governing most industrialized countries (Swinburn et al., 1999; Jaacks et al., 2019), the ever-increasing influence of impulsive behaviors might play a significant role in unhealthy food choices (Pereira et al., 2005; Navarro-Allende et al., 2008; Kakoschke et al., 2017; Jones et al., 2018), PHSs might be an important tool for fighting the obesity epidemic. Another translational value of our results is related to the unsustainability of unhealthy food choices from the environmental perspective (Clark et al., 2019, 2022;

Willett et al., 2019). Hence, the observed increased preferences for healthy food items and decreased choices from the unhealthy category are crucial not only for human health but also for planetary sustainability. However, these results and interpretations need to be replicated by other groups and further investigated before one can draw any conclusion with certainty.

Interestingly, our Bayesian results confirmed that the observed effects of the PHS were not diminishing over a period of more than 1 week. Even though some anecdotal reports suggest the longevity of PHS effects (for review, see Zahedi et al., 2017; Bohmer and Schmidt, 2022), few studies have investigated the question. For instance, Bohmer and Schmidt (Bohmer and Schmidt, 2022) have shown that a safety-promoting PHS was effective over several weeks (*Median* = 49 *days*, *Range* = 7169 *days*) after hypnosis induction. In line with previous reports, our results not only show the longevity of PHS effects but also revealed that these effects are not qualitatively or quantitatively altered. This point has important implications for theories of hypnosis. For instance, it is suggested that the effects of PHSs might be implemented through context-dependent mental practice (Zahedi et al., 2020b). Our results corroborate this hypothesis, as the effects neither diminished nor increased in the absence of renewed hypnosis and PHS. Further, the effects were still confined to a specific context (activation signals), even a week after receiving the PHS.

Another facet of our results critical for hypnosis theories is that changes in preferences and choice behavior for both healthy and unhealthy food categories correlated with participants' hypnotizability scores. Given that hypnotizability itself is a multifactorial construct (Woody et al., 2005; Zahedi and Sommer, 2022), many active researchers in the hypnosis field suggested that participant selection should not be based on hypnotizability (Jensen et al., 2015; Acunzo and Terhune, 2021; Reshetnikov and Terhune, 2022; Zahedi and Sommer, 2022). Our results of a robust relationship between PHS effects and hypnotizability echo these suggestions and indicate the value of using hypnotizability as a regressor for modeling results rather than as a cut-off criterion in participant selection. According to the present findings, even a simple suggestion might have an intricate range of effects implemented *via* different psychological mechanisms. Therefore, the current study strongly suggests that theories of hypnosis, which try to simplify hypnotic phenomena to a single psychological mechanism, are of limited value (Zahedi and Sommer, 2021, 2022; Lynn et al., 2022).

An interesting point regarding our results is the higher preference for healthy food items even when PHS was not activated. This finding is in accordance with other studies, some of which used considerably bigger samples (Blechert et al., 2014; Zahedi et al., 2022). The reason for this initial difference might be related to a multitude of factors (Scaglioni et al., 2018), the discussion of which is outside the scope of the current study. However, regardless of these categorical differences, we found that preferences for different food categories were significantly altered by PHS. When discussing changes in food preferences, we are referring to these significant statistical shifts away from the baseline, which are orthogonal to the comparative structure of preferences for different food categories (e.g., healthy vs. unhealthy food preferences).

Several critical points and limitations should be considered regarding the current study. First, our sample included many female students, which may limit the generalizability of the obtained results. However, qualitatively similar results have been obtained in other studies (Ludwig et al., 2014; Zahedi et al., 2020a), speaking in favor of their stability. Further, we did not introduce budgetary restrictions in the online supermarket task because it might have interacted with or even overshadowed the effects of participants' preferences on their food choices (e.g., Darmon et al., 2002; van Dooren, 2018; Fulgoni III and Drewnowski, 2019). Additionally, there are many other factors that can affect food choices and preferences, including, but not restricted to, genetic and prenatal factors (Maier-Noth, 2019), exposure (Bornstein, 1989), and a multitude of affective (Zahedi et al., 2020a), social, and cultural influences (Enriquez and Archila-Godinez, 2021), which were not included in the current study. The present study's focus was the rather specific question of the efficacy of PHS for altering food preferences and choices and addressing their underlying cognitive mechanisms. Future studies, however, should consider these other factors when investigating food choice behavior using appropriate participant samples. Finally, the present study used a PHS that exclusively targeted healthy food items (Appendix A); therefore, other food categories could have been affected only indirectly. Consequently, future studies should investigate PHSs that (also) target unhealthy food preferences.

In conclusion, the current study used an online-only procedure in a repeated-measures design to address the effects of PHSs on food decisions and their underlying mechanisms. Our results indicate that PHSs can successfully increase preferences and choices of healthy food items in a realistic shopping simulation without altering the relationship between preferences and choices for these items. Hence, the alterations in decision-making were most probably implemented through resolve; in other words, the modulation of preferences resulted in the alteration of choice behavior (Ainslie, 2020). On the other hand, although not directly addressed, preferences for and choices of unhealthy food items were decreased due to the PHS. However, for unhealthy food items, the PHS also modulated the relationship between preferences and choices. Simultaneously, participants became more negatively biased against unhealthy items under the influence of the PHS, but preferences also played a more dominant role in their choices. This result was interpreted as indicating less impulsive unhealthy choices under the influence of the PHS, which were implemented through effortful choice suppression. Further, our results showed qualitative and quantitative persistence of the PHS effects, at least over a period of 1 week, which is in line with other findings (Bohmer and Schmidt, 2022). Finally, our results revealed correlations between the PHS effects and hypnotizability, a multifactorial construct (Zahedi and Sommer, 2022). The present results are not only significant in providing a promising tool for counteracting the overweight and obesity epidemic in modern societies but may also contribute toward greater sustainability of food systems. Furthermore, the results valuably contribute to a better theoretical understanding of hypnosis, hypnotizability, and food decisions in general.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://doi.org/10.17605/OSF.IO/E8H3Q.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee of the Department of Psychology of the Humboldt-Universität zu Berlin (approval number 2021-36). The patients/participants provided their written informed consent to participate in this study.

Author contributions

AB: methods development and manuscript writing. AZ: conceptualization, design, manuscript writing, methodology, and data analysis. JL and RÖ: data acquisition and data pre-analysis. WS: conceptualization, design, and manuscript writing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Appendix

Appendix A: The hypnosis procedure and posthypnotic suggestion

The hypnosis procedure and the posthypnotic suggestion used in this study are similar to (Zahedi et al., 2020a). The hypnosis narration was recorded in German and presented from tape to provide identical wordings for all participants; however, if participants needed further elaboration, some additional suggestions related to relaxation were presented by the experimenter A.Z., a certified hypnotizer who was present in all sessions. These suggestions were either progressive muscle relaxation (PMR), breathing techniques, or other suggestions similar in nature (Hammond, 1990, 1998). Before hypnosis, participants chose either a forest or beach scenario for the following hypnosis narration. The induction and deepening stages of hypnosis (Terhune et al., 2017; Zahedi and Sommer, 2021) were succeeded by a suggestion about feeling a lightness in the body and by the following PHS (translated from German): "While you are responding to the tasks, you will hear the sound of a bell. When you have heard it, you will feel a lightness in your body (bell). The lightness is like what you have sensed before and retained in your fist, but now another feeling also accompanies this lightness, a craving, voracious desire for vegetables, fruits, and all sorts of healthy food. You will have a craving even for pictures of vegetables. Even their picture is so desirable and appealing that it increases your appetite and makes you want to eat them. While you are performing the tasks, whenever you see their picture, your appetite and desire for vegetables and fruits, which are healthy and full of vitamins, will become voracious. This exclusive desire for vegetables and fruits will get stronger and stronger during the session. When you hear the sound of the bell for the second time, everything will go back to normal, like before the first sound of the bell; even your hunger will disappear as if it had never existed; everything will go back to normal."

The PHS was given twice in a row to consolidate the association with the bell ring. Then, hypnosis was terminated with the countback technique (for details, see Hammond, 1990, 1998).