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The effect of daily peanut consumption on cognitive function and indicators of mental health among healthy young women

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ABSTRACT

Background: Peanuts and tree nuts contain many bioactive compounds that may provide health benefits. There is some evidence to suggest that regular consumption of peanuts and peanut butter may improve cognitive function and mood, however, there are no prior studies examining whether daily intake of dry roasted, skinless peanuts improves cognition.

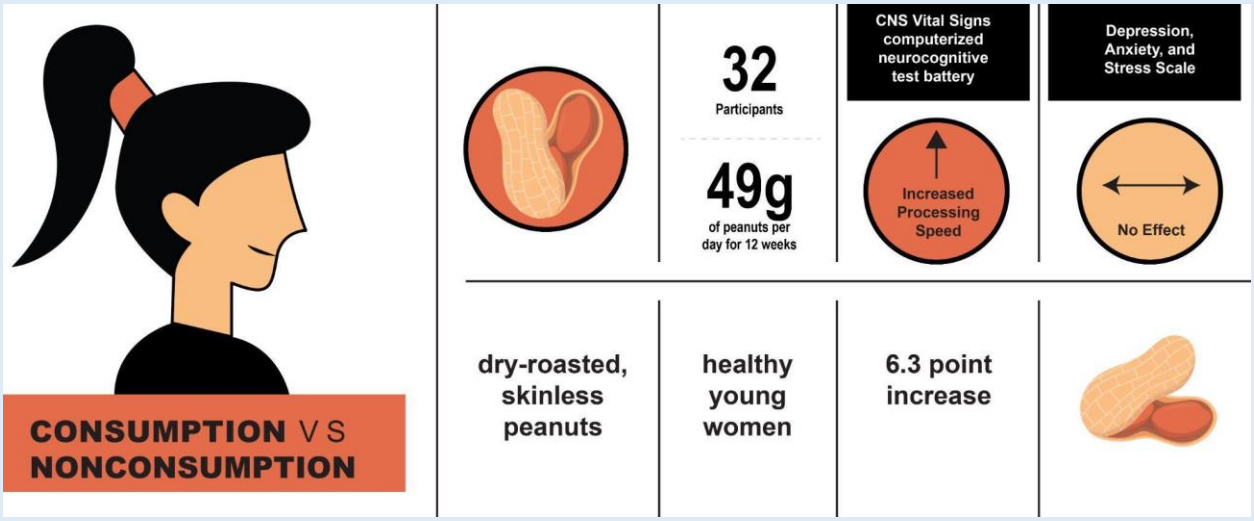
Objective: The objective of this study was to determine the effect of consuming 49 g/day of peanuts for 12 weeks on cognitive function and mental health, compared to consuming a peanut-free diet, among healthy young women.

Methods: This was a pre-post test study of 65 women (n = 32 in peanut group, n = 29 in control group). Participants in the peanut group consumed an individually portioned pack of peanuts each day for 12 weeks. Cognitive function was assessed using the CNS Vital Signs computerized neurocognitive test battery. Mental health was assessed using the Depression, Anxiety, and Stress Scale (DASS-42). Differences in endpoints between groups were assessed using ANCOVA tests.

Results: There was a significant difference between the two groups in reaction time (6.9 points; p = 0.029), with the control group having a greater increase in scores. There was a significant within-group effect of peanuts on processing speed, with the peanut group increasing scores by 6.3 points (95% CI: 2.7, 9.8). There was no effect of peanut consumption on depression, anxiety, or stress scores.

Conclusion: Further research is needed to fully understand the effect of different types of peanut products on cognition.

Keywords: cognition, mental health, peanuts, nuts



INTRODUCTION:

Habitual nut intake is associated with numerous health benefits such as reduced risk of cardiovascular disease, type II diabetes, and metabolic syndrome [1–3]. Nuts (including peanuts and tree nuts) contain an array of beneficial antioxidants, phytochemicals, and healthy fats, all of which may contribute to their beneficial association with health [4]. Regular consumption of nuts may help reduce inflammation, reduce oxidative damage, and improve vascular function, which in turn may benefit cognitive function [5–7].

Nut consumption has been associated with lower depression scores and better cognitive function in a number of large observational studies [8–11]. While many epidemiological studies have shown positive associations between nut consumption and cognition, results from randomized controlled trials have been more inconsistent. Data from the PREDIMED study found that healthy adults who consumed a Mediterranean diet supplemented with 30 g/day of a mix of walnuts, hazelnuts, and almonds had better scores for cognitive function and memory after 4-6 years compared to adults who were consuming a low-fat diet [12-13]. On the other hand, shorter trials of almonds only or walnuts only haven't demonstrated as strong of an association with cognitive function or mood [14–16]. Consumption of almonds for 12 weeks, in a portion size of 15% of participants estimated energy requirements, resulted in no significant changes in cognitive performance or mood among overweight older adults, though, there were improvements in triglyceride and blood pressure levels seen with almond consumption [14]. A longer study that also had participants consume almonds daily found that after six months of dietary intervention, no significant improvements in cognitive function were observed among the healthy, upper-middle aged adults in the study [15]. Finally, in a study looking at college students, consumption of a banana bread made with finely ground English walnuts for eight weeks resulted in improved inferential reasoning, but no improvements to non-verbal reasoning, memory, or mood [16]. A few studies

have also focused on the effects of different peanut products on cognitive function and mood, which have suggested that peanuts may be beneficial for brain health [7,17-18]. Cross-sectional data from the National Health and Nutrition Examination Survey (NHANES) suggested that older adults ages 60+ who reported not consuming any peanuts or peanut butter in their two 24-hr dietary recalls had a higher chance of scoring lower on a series of cognitive function tests [18]. Data from a randomized controlled trial examining consumption of roasted peanuts with skins for six months found that the roasted peanuts with skins decreased anxiety compared to a control peanut oil-based butter [17]. Finally, consumption of high-oleic peanuts with skins for 12 weeks improved short-term memory, verbal fluency, and processing speed in a study of overweight, middle-aged adults [7].

The effect of tree nuts and peanuts on cognitive function and mood may relate to their polyphenol content. Polyphenols are a class of naturally occurring compounds that includes phenolic acids, flavonoids, stilbenes, and lignans [19]. Peanuts are a particularly good source of the stilbene resveratrol, which has been extensively studied for its protective effects against certain cancers, heart disease, Alzheimer's disease, and stroke [20]. Other polyphenols in peanuts include coumaric acid and various flavonoids [20]. Previous research has suggested that resveratrol is neuroprotective and may help prevent or slow aging related neurodegeneration [21] and is a potential candidate for use in treatment of mental disorders such as depression and anxiety [22]. Resveratrol also may improve memory and overall cognitive performance [23-24]

While peanuts are technically classified as legumes, their nutritional characteristics are similar to tree nuts, so the two are often grouped together broadly as nuts. The 2020-2025 Dietary Guidelines for Americans recommends that an adult consuming a 2,000 kcal/day diet consume 5 oz-eq/week of nuts as part of a healthy dietary pattern, and most Americans consume close to this recommended level [25]. Peanuts make up a large portion of the nuts and seeds consumed as part of this food group, and peanut consumption has steadily increased the past ten years from 6.5 to 7.9 lbs. per capita [26]. Peanuts are a good source of unsaturated fatty acids, plant-based protein, and fiber, and they have a low glycemic index and glycemic load [20]. The exact nutritional composition of peanuts, however, varies somewhat depending on what form they are eaten in. For example, the resveratrol content of peanut butter is about three times higher than the resveratrol content of roasted peanuts with skins, and total phenolic content of peanuts is higher when peanuts are consumed with skins versus without skins [20,27]. Since the nutritional composition of peanuts varies depending on their form, the effect of peanut consumption on health parameters such as cognitive function or mood may vary depending on the type of peanut consumed. Thus, we sought to examine the effect of regular consumption of dry roasted, skinless peanuts, which is a familiar, commonly consumed peanut snack, on various components of cognitive function and depression, anxiety, and stress scores in a group of healthy young women.

METHODS

Study Design: This pre-post study was conducted at Mississippi State University between November 2021 and May 2022. Eligible individuals were randomly assigned to either the intervention (peanut) group (49 g/day as snacks, n = 40), or the control group (a peanut-free diet). Randomization was done prior to baseline testing by use of a computer-generated randomization scheme via the website randomizer.org. Participants were not blinded to the randomization due to the nature of the study. Participants in the peanut group received pre-portioned packets of peanuts and were instructed to eat one pack per day as a snack for the duration of 12 weeks. Outcomes were measured at baseline and at the end of the diet period. Study compliance was monitored

via weekly check-in text messages where participants in the peanut group were asked to report how many days that week they consumed their peanuts and participants in the control group were asked whether or not they had any instances of peanut consumption that week. This study protocol was approved by the Mississippi State University Institutional Review Board (IRB 21-260). All participants provided written informed consent prior to beginning the study.

Participants: Participants were recruited between November 2021 and February 2022 from the Starkville, Mississippi area. Recruitment was conducted by means of flyers posted on university bulletin boards and recruitment emails circulated on listservs. Women ages 18 and older who were enrolled as students at Mississippi State University were eligible to participate. Prospective participants with any history of cardiovascular, gastrointestinal, liver, or kidney disease, or any peanut allergies were not eligible to participate. Seventy-five participants were recruited in order to ensure complete data could be collected from sixty participants while accounting for a 25% drop out rate. Participants were screened after they reached out to study coordinators indicating their interest in the study. Participants were first screened via email, and those that met study criteria and remained interested in participating after receiving further information were scheduled to come in for an initial appointment. A total of 86 participants were screened, and a total of 75 participants were enrolled. Participants received weekly reminders via text message to support study compliance, and each Friday participants completed a weekly check-in to report the number of packs of peanuts they consumed over the week (for the intervention group), or the number of incidents of accidental peanut consumption (for the control group).

Intervention: The experiment snack was 49 g /day (1.75 oz) of pre-packaged dry-roasted peanuts (290 calories per serving), consumed for 12 weeks. This quantity was chosen in consultation with prior literature [7,17] and based on choosing a quantity of peanuts that would be representative of a typical snack portion. Participants in the intervention group were permitted to consume additional peanut-containing foods throughout the 12 weeks if they desired. Participants were not given a specific time of day to consume the snack due to the variability of college students' schedules. The control group was instructed to avoid consuming peanuts or foods containing peanuts for 12 weeks, and all control group participants were counseled on foods that commonly contain peanuts and how to check food labels to check for peanut content.

All participants were encouraged to otherwise maintain their usual diet and physical activity routine, and to not make any major lifestyle changes during the study period.

OUTCOMES

Cognitive function: All participants were administered a cognitive function assessment at baseline and endline (CNS Vital Signs (CNSVS), Morrisville, NC, USA). CNSVS is a validated, computer-based set of neurocognitive tests [28]. To complete the cognitive assessment, participants were seated in front of a laptop computer with a full QWERTY keyboard. A research assistant briefed participants on the structure of the test and how to navigate throughout the test using the keyboard before the assessment began. Each test within the assessment started with a practice session to ensure participants understood instructions. Participants completed the assessment in a quiet room to minimize distractions. A research assistant remained nearby in case of questions or any technical difficulties.

The battery of tests assessed verbal memory, visual memory, reasoning, executive function, psychomotor speed, complex attention, and cognitive flexibility. Scores for each of these cognitive domains were calculated from the eight individual functional tests that were

administered: verbal memory, visual memory, non-verbal reasoning, shifting attention, finger tapping, symbol-digit coding, Stroop test, and the continuous performance task test. Scores for some cognitive domains are based on a combination of individual tests. The psychomotor speed domain score was calculated by combining scores from the finger tapping test and the symbol-digit coding test. The complex attention domain was calculated from Stroop test, shifting attention, and continuous performance task test scores. Finally, the cognitive flexibility domain was calculated from the shifting attention test and Stroop test. A global neurocognition score was also calculated, the neurocognitive index, which is an average of the composite memory, psychomotor speed, reaction time, complex attention, and cognitive flexibility domain scores.

Mental health: Participants completed a mental health assessment, the 42-item Depression, Anxiety, and Stress Scale (DASS-42) at baseline and endline [29]. This survey assesses the severity of core symptoms of depression, anxiety, and stress experienced over the previous week, with 14 questions corresponding to each domain. Each response was scored with zero ("did not apply to me") through three (applied to me "very much or most of the time") points, based on the prevalence of the symptom. Higher scores in each domain are indicative of more severe depression, anxiety, and/or stress.

Dietary intake: Each participant completed two 24-hour recalls throughout the study to assess dietary intake. The first 24-hour recall was administered prior to baseline, and the second 24-hour recall was administered in the participant's final week in the study. The Automated Self-Administered 24-Hour Dietary Assessment Tool (ASA24) from the National Cancer Institute (NCI) was used and the tests were administered according to NCI Dietary Assessment Primer guidelines [30]. To complete the recall, participants were e-mailed a unique username and password prior to baseline and endpoint data collection visits and asked to complete the 24-hour recall prior to their study appointment. Dietary recalls where energy intake was <600 or >4400 kcal/d were excluded from the analyses based on the NCI guidelines for cleaning ASA24 data [31].

Participants also had their skin carotenoid levels measured at baseline and endline via a reflection spectroscopy device (VeggieMeter®, Longevity Link Inc., Salt Lake City, UT, USA). This non-invasive test measures the level of carotenoids stored in a person's skin by scanning the tip of the finger. Higher scores on the Veggie Meter indicate higher carotenoid levels, which may serve as a biomarker of typical fruit and vegetable intake [32 - 33].

Statistical analyses: A complete case analysis was conducted where any participants who dropped out prior to study endline and therefore had missing post-test data were not included in the analysis. Descriptive statistics were calculated for variables of interest at baseline (means and standard deviations for continuous variables and frequencies and percentages for categorical variables). T-tests and chi-square tests were carried out to determine whether or not the peanut and control groups significantly differed from each other in any way at baseline. Variables were assessed for normality visually using QQ plots and log-transformed where necessary. The effect of each group (peanut vs control) on outcome variable was examined using a series of ANCOVA tests with endline scores as the dependent variable and baseline scores included as a covariate.[34] Race, degree of diet compliance, and student classification were additionally included as covariates. An exploratory sub-analysis of participants with depression at baseline was also conducted to examine the effect of the intervention on depressive scores for participants who began the study with mild or moderate depression. Change from baseline for depression scale scores was calculated by subtracting the end point value from the

baseline value and mean changes in score were calculated for each group. All statistical analyses were conducted using a two-tailed family-wise alpha threshold of 0.05, and all analyses were performed using SAS (version 9.4; SAS Institute Inc).

RESULTS

Seventy-five students were randomly assigned out of the 88 students who were screened. Of the 75 individuals who were randomly assigned, 65 individuals completed the study. The final data analysis included 61 women. Four participants were removed from the final data analysis for either missing baseline or endline cognitive function scores (n=3) or implausible cognitive function scores (n=1). The 61 women included in the final analysis had a mean age of 20.1 ± 1.5 years (Table 1). Most were White (73.8%), of a healthy weight BMI, and sophomores in college. Mean baseline neurocognitive index scores were considered "average" compared to an age-matched normative sample of healthy subjects [35]. Participants' mean baseline depression, anxiety, and stress scores were also classified as normal [36]. Participants in the peanut group reported consuming their peanuts an average of 83.9% of the days, and participants in the control group reported abstaining from peanut consumption 95.8% of the days. One participant in the peanut group reported 0% compliance (not consuming any peanuts) but was still included in the analysis consistent with intent-to-treat principles [37]. It is unclear if this participant actually had 0% compliance with the intervention or if they did not understand the compliance reporting procedure. An additional analysis run with this participant included, however, did not significantly change any results. The demographic characteristics of the peanut group and control group did not significantly differ from one another. The only significant difference between groups observed at baseline was for psychomotor speed scores, with the control group having higher scores at baseline ($p = 0.036$). Dietary intake at baseline did not significantly differ between participants randomized to the peanut group and participants randomized to the control group in regard to energy intake and total carbohydrate, fat, and protein intake (Table 2). When looking at food groups, the control group reported a significantly higher total of grain intake and refined grains intake at baseline. Within-group differences indicated that energy intake, total fat intake, monounsaturated fat intake, polyunsaturated fat intake, fiber, refined grains, and intake of foods from the nuts/seeds group all increased during the study period in the peanut group. Dietary intake for the control group remained unchanged from baseline to endline. Between-group dietary differences at the endline suggested that participants in the peanut group were consuming more nuts/seeds ($p = 0.003$), while participants in the control group were consuming more fruit ($p = 0.038$). Energy intake at the endline did not differ between the two groups. Finally, veggie meter scores, a proxy for fruit and vegetable intake, indicated no within or between group differences in total fruit and vegetable intake at baseline or endline. No significant between-group effects were observed for depression (peanut vs control group mean difference: 0.2 points; 95% CI: -2.8, 3.2), anxiety (0.9 points; 95% CI: -2.1, 3.9), or stress scores (-0.7 points; 95% CI: -4.1, 2.7) (Table 2). Regarding cognitive function, no differences were observed between the peanut group and the control group for the NCI, composite memory, verbal memory, visual memory, psychomotor speed, complex attention, cognitive flexibility, processing speed, executive function, simple attention, or motor speed. There was a significant difference in reaction time scores from baseline and endline between the two groups ($p = 0.029$), with the control group scoring higher than the peanut group (mean difference: 6.9 points; 95% CI: 0.7, 13.0). Within group differences from baseline to endline for the peanut group indicated a significant increase in processing speed following peanut consumption (6.3 points; 95% CI: 2.7, 9.8). There were no within group differences from baseline to endline for the control group.

Table 1. Baseline characteristics of study participants

Characteristic	Overall (n=61)	Peanut group (n=32)	Control group (n=29)	*P*[1]
Age, *mean ± SD*	20.1 ± 1.5	20.3 ± 1.7	19.9 ± 1.4	0.335
Race, *n (%)*				0.692
White	45 (73.8)	23 (71.9)	22 (75.9)	
Black	6 (9.8)	3 (9.4)	3 (10.3)	
Multi-racial	4 (6.6)	2 (6.3)	2 (6.9)	
Other	6 (9.8)	4 (12.5)	2 (6.9)	
BMI, *mean ± SD*	24.5 ± 4.7	23.8 ± 4.1	25.2 ± 5.3	0.221
Year in school, *n (%)*				0.355
Freshman	5 (8.2)	2 (6.3)	3 (10.3)	
Sophomore	22 (36.1)	9 (28.1)	13 (44.8)	
Junior	14 (23.0)	9 (28.1)	5 (17.2)	
Senior	13 (21.3)	9 (28.1)	4 (13.8)	
Graduate Student	7 (11.4)	3 (9.4)	0 (0.0)	
VeggieMeter, *mean ± SD*	284.0 ± 91.5	284.3 ± 97.1	283.7 ± 86.5	0.979
Cognitive Function, *mean ± SD*				
NCI	99.0 ± 8.5	97.5 ± 9.1	100.6 ± 7.7	0.163
Composite Memory	105.6 ± 14.0	105.4 ± 13.2	105.8 ± 15.0	0.908
Verbal Memory	101.9 ± 23.8	102.8 ± 23.9	100.9 ± 24.2	0.769
Visual Memory	104.2 ± 12.2	103.3 ± 11.7	105.1 ± 12.9	0.559
Psychomotor Speed	100.2 ± 11.6	97.3 ± 12.3	103.4 ± 9.9	**0.036**
Reaction Time	97.1 ± 17.4	96.4 ± 13.0	97.9 ± 21.4	0.746
Complex Attention	96.2 ± 14.5	96.5 ± 12.4	95.9 ± 16.8	0.866
Cognitive Flexibility	93.4 ± 15.8	92.1 ± 15.9	94.9 ± 15.8	0.488
Processing Speed	103.1 ± 12.5	100.5 ± 12.1	100.9 ± 12.5	0.092
Executive Function	92.3 ± 18.6	92.3 ± 16.0	92.3 ± 21.4	0.999
Simple Attention	94.0 ± 19.8	93.3 ± 18.7	94.7 ± 21.3	0.794
Motor Speed	97.1 ± 14.5	95.8 ± 11.1	98.6 ± 17.5	0.453
DASS-42, *mean ± SD*				
Depression	3.7 ± 4.0	3.5 ± 4.1	3.8 ± 3.9	0.800
Anxiety	5.1 ± 4.1	5.4 ± 4.7	4.7 ± 3.4	0.544
Stress	8.6 ± 6.1	8.7 ± 6.7	8.5 ± 5.5	0.913

SD, standard deviation. BMI, body mass index. NCI, neurocognitive index. [1]p-values calculated from chi-square tests for categorical variables or t-tests for continuous variables

Table 2. Dietary patterns of participants at baseline and endline

	Peanut Group (n=30)			Control Group (n=28)			Between group difference (baseline)	Between group difference (endline)
DASS-24	Baseline	Endline	p-value[1]	Baseline	Endline	p-value[1]	p-value[2]	p-value[3]
Energy, kcal	1596.0 ± 665.6	2088.5 ± 773.0	**0.006**	1885.4 ± 612.0	2038.8 ± 657.3	0.357	0.091	0.818
Carbohydrate, g	180.1 ± 78.8	218.4 ± 87.7	0.148	218.7 ± 69.8	239.2 ± 86.8	0.144	0.054	0.425
Protein, g	64.1 ± 32.0	81.1 ± 32.5	0.069	69.6 ± 30.7	71.2 ± 33.3	0.595	0.505	0.313
Fat, total, g	71.6 ± 34.9	96.8 ± 43.1	**0.004**	80.8 ± 31.7	90.4 ± 35.7	0.347	0.302	0.589
Saturated fat, g	23.2 ± 13.3	29.3 ± 15.2	0.059	26.3 ± 15.7	27.7 ± 13.0	0.843	0.430	0.708
Monounsaturated fat, g	24.6 ± 13.2	35.2 ± 15.1	**0.003**	28.2 ± 11.2	32.3 ± 15.8	0.407	0.271	0.524
Polyunsaturated fat, g	17.6 ± 8.8	24.4 ± 12.8	**0.014**	19.3 ± 9.2	23.2 ± 11.7	0.068	0.481	0.741
Fiber, g	14.2 ± 7.8	18.4 ± 8.9	**0.042**	15.1 ± 8.1	17.7 ± 11.9	0.559	0.692	0.807
Grains, total, oz eq.	4.2 ± 2.4	6.4 ± 2.9	**0.009**	6.9 ± 3.3	6.0 ± 2.9	0.474	**0.00007**	0.652
Whole grains, oz eq.	0.43 ± 0.64	0.62 ± 1.2	0.412	0.86 ± 1.4	0.65 ± 0.88	0.239	0.132	0.930
Refined grains, oz eq.	3.7 ± 2.3	5.8 ± 2.9	**0.019**	6.0 ± 3.8	5.3 ± 2.8	0.841	**0.008**	0.630
Fruit, total, cup eq.	0.51 ± 0.92	0.33 ± 0.82	0.654	0.53 ± 0.69	0.95 ± 1.12	0.096	0.930	**0.038**
Fruit (citrus, melons, and berries), cup eq.	0.18 ± 0.45	0.11 ± 0.30	0.805	0.12 ± 0.34	0.17 ± 0.34	0.952	0.623	0.514
Vegetables, total, cup eq.	1.5 ± 1.3	1.5 ± 1.0	0.939	1.3 ± 0.9	1.9 ± 1.7	0.155	0.396	0.331
Nuts/seeds, oz eq.	0.63 ± 1.1	2.3 ± 2.4	**0.006**	0.60 ± 1.0	0.54 ± 1.5	0.575	0.920	**0.003**
Total dairy products, cup eq.	1.5 ± 1.2	1.3 ± 0.91	0.433	1.4 ± 1.1	1.5 ± 1.2	0.828	0.896	0.458
Sodium, mg	2756.2 ± 1327.9	3201.4 ± 1269.3	0.343	3046.9 ±892.7	3295.1 ± 1409.1	0.562	0.336	0.814
Added sugars, tsp eq.	12.1 ± 9.2	14.7 ± 11.3	0.357	14.1 ± 7.8	17.2 ± 9.2	0.053	0.382	0.422
Veggie Meter	284.3 ± 97.1	278.2 ± 97.8	0.465	283.7 ± 86.5	268.2 ± 86.4	0.162	0.979	0.676

[1]Within group differences. P-values calculated from paired sample t-tests. [2]Between group differences in baseline scores. P-values calculated from independent samples t-tests.
[3]Between group differences in endline scores. P-values calculated from independent samples t-tests. Eq., equivalent. Values are means ± SD.

Table 3. Comparison of baseline and endline scores for mental health and cognitive function parameters[1]

	Peanut Group (n = 32)			Control Group (n = 29)				
Outcome	Baseline	Endline	Within-group difference	Baseline	Endline	Within-group difference	Between-group Effect[2]	Between-group *p*-value[3]
DASS-42								
Depression	3.5 ± 4.1	4.7 ± 5.7	1.1 (-0.6, 2.9)	3.8 ± 3.9	4.9 ± 6.3	1.1 (-0.8, 3.0)	0.2 (-2.8, 3.2)	0.871
Anxiety	5.4 ± 4.7	5.1 ± 6.7	-0.3 (-2.1, 1.4)	4.7 ± 3.4	5.5 ± 6.2	0.8 (-1.3, 2.8)	0.9 (-2.1, 3.9)	0.530
Stress	8.7 ± 6.7	8.8 ± 7.0	0.1 (-1.9, 2.1)	8.5 ± 5.5	8.6 ± 8.2	0.1 (-2.2, 2.4)	-0.7 (-4.1, 2.7)	0.667
Cognitive Function								
NCI	97.5 ± 9.1	97.9 ± 10.8	0.3 (-3.1, 3.7)	100.6 ± 7.7	100.4 ± 9.7	-0.1 (-3.9, 3.7)	2.0 (-3.2, 7.4)	0.452
Composite Memory	105.4 ± 13.2	103.8 ± 18.5	-1.6 (-8.5, 5.2)	105.8 ± 15.0	105.6 ± 12.4	-0.3 (-6.3, 5.7)	1.7 (-7.0, 10.4)	0.692
Verbal Memory	102.8 ± 23.9	105.3 ± 16.5	2.5 (-6.8, 11.9)	100.9 ± 24.2	104.5 ± 12.4	3.6 (-5.1, 12.2)	-0.7 (-9.2, 7.7)	0.868
Visual Memory	103.3 ± 11.7	101.6 ± 18.8	-1.7 (-8.2, 4.9)	105.1 ± 12.9	104.5 ± 12.7	-0.6 (-6.6, 5.4)	2.6 (-6.1, 11.3)	0.554
Psychomotor Speed	97.3 ± 12.3	100.1 ± 13.6	2.8 (0.4, 5.3)	103.4 ± 9.9	102.9 ± 10.7	-0.5 (-4.7, 3.7)	-1.7 (-6.9, 3.6)	0.529
Reaction Time	96.4 ± 13.0	96.4 ± 12.7	-0.03 (-3.4, 3.4)	97.9 ± 21.4	103.8 ± 10.8	5.9 (-1.8, 13.6)	6.9 (0.7, 13.0)	**0.029**
Complex Attention	96.5 ± 12.4	93.9 ± 20.7	-2.6 (-11.3, 6.1)	95.9 ± 16.8	92.9 ± 26.1	-3.0 (-10.8, 4.8)	3.5 (-9.8, 16.8)	0.603
Cognitive Flexibility	92.1 ± 15.9	94.9 ± 14.4	2.8 (-3.3, 9.0)	94.9 ± 15.8	96.6 ± 19.2	1.7 (-4.7, 8.1)	3.1 (-5.9, 12.0)	0.497
Processing Speed	100.5 ± 12.1	106.8 ± 13.7	**6.3 (2.7, 9.8)**	105.9 ± 12.5	108.0 ± 13.0	2.1 (-1.7, 5.8)	-4.1 (-9.5, 1.4)	0.139
Executive Function	92.3 ± 16.0	95.6 ± 13.5	3.3 (-2.7, 9.2)	92.3 ± 21.4	98.2 ± 18.0	5.8 (-4.0, 15.6)	5.0 (-4.2, 14.2)	0.284
Simple Attention	93.3 ± 18.7	82.8 ± 39.8	-10.5 (-26.4, 5.5)	94.7 ± 21.3	89.2 ± 34.3	-5.4 (-18.4, 7.5)	6.6 (-15.1, 28.4)	0.543
Motor Speed	95.8 ± 11.1	95.5 ± 13.0	-0.3 (-2.6, 1.9)	98.6 ± 17.5	98.4 ± 11.0	-0.2 (-6.3, 6.0)	2.1 (-3.2, 7.3)	0.431

[1]Baseline and endline values are mean ± standard deviation. [2]Values are least squares mean effect estimate and 95% CI. [3]P-values from ANCOVA adjusted for baseline scores, race, percent compliance, and student classification. P-value represents the main effect of group. NCI, neurocognitive index.

Finally, we looked at the subset of participants who scored greater than 10 points on the depression component of the DASS-42 at baseline, indicating mild or greater depression at the beginning of the study. This was a very small subset of participants (n = 6, three per group) as our recruitment focused on healthy young women. While this subsample was too small to conduct any formal analyses on, the peanut group had a mean decrease of 5.33 points on the depression component of the DASS-42 from baseline to endline, while the control group had a smaller mean decrease of only 1.67 points from baseline to endline for participants with depression at baseline (Table 4). Baseline to endline changes in scores ranged from 0 to -9 points for those in the peanut group and +1 to -3 points for those in the control group.

Table 4. Between group differences in depression scores from baseline to endline for participants with depression at baseline

	Baseline depression score	Endline depression score	Raw Difference	Mean Difference
Peanut group				-5.33
Participant 1	16	9	-7	
Participant 2	13	13	0	
Participant 3	11	2	-9	
Control Group				-1.67
Participant 1	16	13	-3	
Participant 2	13	14	+1	
Participant 3	10	7	-3	

DISCUSSION

In this present study, consuming 49 g/day of dry roasted salted peanuts without skins for 12 weeks did not appear to increase scores on a cognitive function assessment compared with usual diet consumption among healthy young adult women. In addition, peanut consumption in healthy young adult women did not appear to decrease scores on a depression, anxiety, and stress scale survey. However, peanut consumption did significantly increase processing speed time from baseline to endline among participants in the peanut group. Participants in the peanut group also significantly increased their intake of energy, fat, fiber, and nuts/seeds from baseline to endline. However, they also significantly increased their intake of refined grains from baseline to endline. Finally, an exploratory look at changes in depression scores among a small subset of participants who had depression upon entering the study, found that participants with depression in the peanut group had a greater reduction in depression scores at the endline compared to participants with depression who did not consume peanuts. Overall, for healthy, young adult women, daily consumption of dry roasted, skinless, salted peanuts for 12 weeks does not appear to significantly improve overall cognitive function or depression, anxiety, and stress scores. However, the significant within-group increase in psychomotor speed following daily peanut consumption for 12-weeks suggests that further research is warranted to explore the effect of peanut consumption on this specific component of cognitive function.

Previous research has found intake of roasted peanuts with skins and peanut butter to be associated with improvements in certain components of cognitive function and mood [7,17]. Daily consumption of 56-84 g

of high-oleic peanuts with skins for 12 weeks was shown to improve short-term memory, verbal fluency, and processing speed among overweight, but otherwise healthy, 50-75 y old adults [7]. Among these upper-middle-aged adults (mean age of 65 years), processing speed on a coding test increased 2.2 ± 0.7 points compared to the control group. While we did not find a significant between-group difference in processing speed in our study, scores on the symbol digit coding test that were used to measure processing speed, increased by 6.3 points for the peanut group, but only 2.1 points for the control group. Another study, the ARISTOTLE study, found that healthy young adults who consumed 25 g/day of roasted peanuts with skins, or 32 g/day of peanut butter for six months had within-group improvements in scores for immediate memory, anxiety, and depression from baseline to endline, though, the only significant difference in cognitive function or mental health scores when the peanut or peanut butter groups were compared to the control group was for anxiety [17]. The improvements in cognitive function and mental health found in the ARISTOTLE study were significantly associated with polyphenol intake. This could explain why improvements in cognitive function for the peanut group in our study were not as strong as improvements seen in the peanut/peanut butter groups in the ARISTOTLE study, because the quantity of polyphenols in peanuts and peanut products varies depending on how the peanut was processed. Roasted peanuts without skins, which were used in the present study, contain less resveratrol than roasted peanuts with skins and peanut butter, and contain less total polyphenol compounds than peanuts with skins [38-39]. Polyphenols have been associated with cognitive function and decreased depression, and most of the polyphenols in peanuts are found in the skins [40-41]. Thus, participants in our current study were not only consuming a somewhat smaller quantity of peanuts than the above two mentioned studies, but they were also consuming a peanut product that contained a lower quantity of polyphenols compared to participants in Barbour's study and in the ARISTOTLE study. In the United States, however, the most commonly consumed peanut products consist of just the peanut kernel and not the skins, such as peanut butter, peanut snacks, and peanut candy [42]. Thus, we thought it was important to also examine the effect of peanuts on human health using a common snacking peanut that is familiar to US consumers.

Strengths of our study include a randomized design with two well matched groups at baseline and relatively good dietary compliance (84% and 96% for the peanut and control groups, respectively). By recruiting a fairly homogenous study sample of all women, with the same highest attained level of education, and of the same age, we were able to control for many confounding variables that can influence performance on cognitive function assessments. Another strength was the use of a computerized neurocognitive test with millisecond precision at measuring items such as processing speed, and inclusion of a validity indicator to evaluate whether or not the test-taker put forth reasonable effort on the test. A weakness of the study was the inability to double-blind the intervention, and the exclusion of a cross-over component due to time-restraints on the school year and all of our participants being undergraduate students who typically travel home for a month between fall and spring semesters, and again travel home for three months in the summer. Additionally, since our recruitment focused on healthy young adults and very few participants had depression at baseline, this made it more difficult to demonstrate an effect of peanuts on DASS-42 scores. Similarly, lower cognitive function scores have been observed with obesity, aging, and lower attained education levels, [43–45] which may have made it more difficult to detect changes in cognitive function in this study population since our participants were healthy weight young women enrolled in college. Nevertheless,

studying the effects of one particular food on health is a challenging endeavor because as intake of one food in the diet increases, intake of other foods must also decrease to compensate. Additionally, foods are not consumed in isolation, and even then, it is difficult to discern the effects of a single food from the effects of each individual compound making up that food. When the outcome of interest can be affected by various environmental, socioeconomic, and biological factors such as cognitive function or mental health, this makes it even more difficult to discern the effect of specific foods on these outcomes since there are countless external confounding variables to consider. The results of this study should thus be considered in light of these strengths and limitations.

CONCLUSION

In conclusion, there is some evidence to suggest that peanuts may have a positive effect on cognition; however, the effect of peanuts on cognitive function and mood may depend on the type of peanut consumed. While we found a significant improvement in processing speed following 12 weeks of peanut consumption, dry roasted, skinless peanuts may offer fewer benefits to brain health compared to peanuts that have a higher quantity of polyphenols such as roasted peanuts with skins or peanut butter. These findings are relevant to the health of a vast array of populations considering that peanuts are a highly accepted and commonly consumed food worldwide, making them a significant source of dietary polyphenols. Given the many bioactive compounds contained in peanuts, and prior literature suggesting their health benefits, peanuts may be classified as a functional food. A functional food, as defined by the Functional Food Center, is a "natural or processed food that contains biologically-active compounds, which, in defined, effective, non-toxic amounts, provides a clinically proven and documented health benefit utilizing specific biomarkers, to promote optimal health and reduce the risk of chronic/viral diseases and manage their symptoms" [46]. Further study of the effect of different peanut products with varying quantities of polyphenols may aid in the development of functional food products that could benefit brain health. Future studies may also wish to examine the effect of higher polyphenol peanut products on cognition and mood in populations with cognitive impairment or depression at baseline, as these populations may benefit the most from this type of intervention.

List of abbreviations used: ASA24: Automated Self-Administered 24-hour dietary assessment tool, BMI: Body Mass Index, CNSVS: CNS Vital Signs, DASS-42: Depression, Anxiety, and Stress Scale-42, NCI: neurocognitive index, NHANES: National Health and Nutrition Examination Survey.

Competing interests: None.

Author contributions: TTP, GA, and NR designed the research. NR, GA, ED, and EM conducted research. NR analyzed the data and wrote the first draft of the manuscript. TTP, GA, ED, and EM reviewed the manuscript. All authors reviewed and approved the final version of the paper.

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