The Effects of Breakfast and Breakfast Composition on Cognition in Adults[1–3]

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ABSTRACT

Extensive literature has addressed the acute cognitive effects of breaking a fast. Recent reviews in this line of work have synthesized available research on the cognitive consequences of fasting compared with nutrient intake and the cognitive effects of macronutrient consumption. These largely have been inconclusive, possibly in part because of selection criteria limiting the scope of studies covered. The purpose of the current review is to integrate the results of the literature examining the cognitive effects of breakfast and breakfast composition in adults with the use of a flexible definition of breakfast, specifically, any caloric intake after a fasting period of ≥8 h. This review includes 38 studies that examine the acute cognitive impact of breakfast and 16 studies that examine the effects of breakfast composition. Results suggest that healthy adults show a small but robust advantage for memory (particularly delayed recall) from consuming breakfast. Largely equivocal results emerge for attention and motor and executive function; there were no effects from breakfast on language. Regarding breakfast composition, a smaller number of studies and widely disparate methodology addressing this question preclude definitive conclusions about the effects of cognition. A subset of this literature examines these questions in the context of glucoregulation; the findings emphasize the importance of considering differences in glucoregulation in research designs, even among healthy cohorts. The limitations of this literature include methodologic differences, such as the use of different tests to measure cognitive constructs, as well as the effects of timing in test administration. *Adv Nutr* 2016;7(Suppl):576S–89S.

Keywords: cognitive function, dietary intake, dietary patterns, breakfast, memory, fasting

Introduction

Of all daily eating occasions, breakfast is of the highest quality from a dietary perspective (1), yet the frequency of breakfast consumption has declined in recent decades (2). This trend has the potential to exert negative effects on cognition, with past work demonstrating positive associations between breakfast consumption and cognitive function. For example, habitual breakfast consumption is associated with better cognitive performance and academic achievement (3–8).

Several studies have examined this link experimentally, with previous reviews of this work addressing the cognitive consequences of fasting, as well as the impact of meal composition (9–11). Benau et al. (9) recently reviewed evidence from 10 studies that addressed the effects of short-term fasting on cognitive function in healthy adults. Results were largely equivocal across domains of cognition. However, the review omitted a large portion of the literature that may contribute to the understanding of postprandial cognitive effects by excluding studies that used glucose beverages as the comparison group to fasting conditions. In addition, having focused on effects of fasting, the review included studies with fasting periods as brief as 2 or 5 h, and therefore may not have addressed the cognitive effects of breakfast, which typically occur after a longer period without nutritional intake (i.e., overnight).

Regarding meal composition, Dye et al. (10) were the first to review research on the cognitive effects of macronutrient intake, examining studies that investigated any eating occasion. At the time of that study, insufficient data prevented conclusions regarding specific macronutrients. However, findings suggested that hypoglycemia was linked to impaired cognitive performance, and nutritional intake that raised blood glucose was related to better memory and reaction time. More recently, Edefonti et al. (11) examined the cognitive

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effects of meal composition specifically at breakfast, defined as the first meal of the day, and excluding laboratory-developed macronutrient manipulations. Selection criteria led to the identification of 4 studies examining adult samples; the review also covered studies conducted in youths, for whom more data exist. The authors determined that conclusions regarding the effects of breakfast composition on cognition still could not be drawn, but suggested that a breakfast eliciting a lower postprandial glycemic response may benefit cognitive performance.

Because of the inclusion of studies examining fasting periods of very brief duration, meals at any eating occasion, or selection of only studies that used ecologically valid meals, previous reviews do not fully address the question of how cognition is affected by breaking an overnight fast with nutritional intake. We sought to broaden the definition of "breakfast" to any caloric intake, and to focus on studies that used a fasting period of ≥8 h. This definition would be likely to include a larger number of studies, possibly leading to a greater likelihood of detecting a pattern. In addition, given the brain's maturation process, cognitive effects are expected to differ across the lifespan (12), and findings from child and adolescent samples may not generalize to adults; we thus focused on studies only in adult samples.

The purpose of the current review was to examine and synthesize the literature addressing the cognitive effects of caloric intake after a fast of ≥8 h in adults, and determine whether these effects were dependent on the nutritional content of the breakfast consumed. In so doing, we sought to integrate the results of an extensive literature review that may speak to the possible cognitive effects of breakfast in adults.

Methods

Search strategy and search terms. Searches of electronic databases were initially carried out between 30 June and 3 July 2014 via Web of Science, PubMed, and PsycInfo. Databases searched were from 1950 to July 2014. The same search was repeated on 10 May 2015. Specific search terms used included breakfast, "morning meal," "first meal," fasted, fasting, memory, attention, recall, "problem solving," and cognit*. In addition, in an effort to identify as many relevant studies as possible, reference lists from past reviews (9–11) were examined for possible studies to include. A flow diagram of the selection process for identification and inclusion of studies in the current review, including number of articles excluded at each stage, is detailed in Figure 1. A total of 43 studies meeting the below criteria were selected for the current review.

Inclusion and exclusion criteria. This review was limited to articles published in English in peer-reviewed journals. Papers were included in this review if they met the following criteria: *1*) Subjects were human adults, age ≥18 y; *2*) only experimental manipulations were considered (i.e., observational and cross-sectional studies examining links between breakfast and cognitive outcomes were excluded); *3*) the experimental breakfast manipulation was required to include a period of overnight fasting or a fast of ≥8 h in duration, with subsequent caloric intake; and *4*) for studies examining breakfast composition, only those manipulating carbohydrate, fat, and protein content or glycemic index (GI)[4] or glycemic load (GL) were included. Exclusion criteria included the following: *1*) Studies reporting the effects of interventions at other mealtimes, unless the effects of breakfast were separately reported; and *2*) studies examining the effects of meals with caffeine,

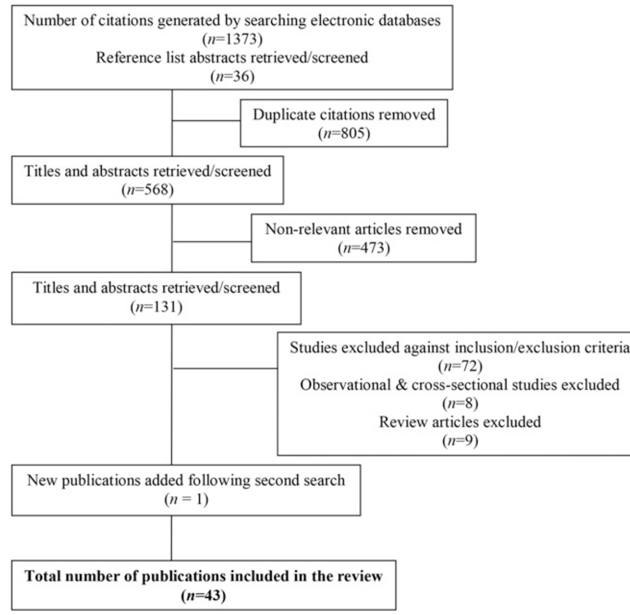

FIGURE 1 Flow diagram of the study selection process.

given the known effects of caffeine on cognition (13), unless the effects of comparison conditions without caffeine were reported separately and the study otherwise met the criteria. Methodologies used in the studies reviewed here included the following: acute comparisons of fasting control and fed conditions, preprandial and postprandial comparisons, and studies evaluating postprandial cognition in breakfasts of differing compositions. Of note, although most of this work has been conducted in healthy individuals, a small number of studies examined this question in the context of impaired glucoregulation; results from these studies are separately described.

Definition of breakfast. As noted above, the intent of this review was to use a broad definition of breakfast. Our definition of breakfast was any caloric intake after an overnight fast or fasting period of ≥8 h in duration. This definition included studies that used ecologically valid meals (i.e., commercially available foods), as well as glucose beverages and macronutrient manipulations in cream, gelatin, and milkshake forms.

Cognitive outcomes. All cognitive dependent variables were accepted. At least 70 different cognitive outcome measures used in this literature were counted, including a mix of experimental and standardized tests. When standardized tests were used, they often incorporated adaptations that altered the test, thus making this estimate quite conservative. Given the large number of tests used, a direct comparison of specific test outcomes would not contribute to the synthesis of the literature. Cognitive variables instead were categorized according to domains, including tasks of learning and memory (verbal and nonverbal), attention/processing, motor skills, executive functions, and language. There are many different conceptualizations regarding how different cognitive tasks associate with one another; the framework used for the current review was adapted from a commonly used approach to understanding cognitive domains (12). A description of cognitive domains and subdomains and a small number of examples of tests used in the literature reviewed is found in Table 1.

Data extraction. A data extraction form was used to consolidate study designs and findings. The results were organized by studies that answered specific search questions: *1*) Does breakfast influence cognition in adults? and *2*) Does the composition of that breakfast influence cognition in adults?

[4] Abbreviations used: GI, glycemic index; GL, glycemic load; T2DM, type 2 diabetes mellitus.

TABLE 1 Cognitive domains, task requirements, and examples of cognitive tests used in the literature reviewed

Cognitive domains and subcomponents	Task requirements	Examples
Attention and processing speed		
Attentional capacity	Accuracy of attention span (e.g., repeating digit sequence)	Digit span (forward)
Vigilance/focus	Sustaining attention over time to detect target stimuli, often with a demand to ignore distractors	Continuous Performance Test, Bakan test
Processing speed	Ability to process information and execute relevant operations within the allotted time	Trail-Making Test (particularly Part A); simple/choice reaction time
Executive functions		
Reasoning/planning	Thinking with conscious intent to reach a conclusion (planning involves induction; reasoning is more deductive)	Graduate and Managerial Assessment Test of Abstract Reasoning; Tower of Hanoi
Inhibitory control	Interruption of a prepotent response	Stroop Color and Word Test
Working memory	Allows information maintained in temporary storage to be manipulated for complex cognitive operations	Paced Auditory Serial Addition Task; Serial 3s, Serial 7s; Brown-Peterson Trigrams; Corsi block-tapping; digit span (backward)
Language		
Semantic processing	Language comprehension and speed of retrieval of information from general knowledge	Experimental semantic processing tasks
Verbal fluency	Oral production of words fitting a specified category (e.g., animals) or beginning with a specified letter	Category fluency; phonemic fluency
Motor		
Gross motor speed	Speeded gross manual dexterity	Simple tapping task
Fine motor speed	Speeded fine manual dexterity	Grooved pegboard
Memory		
Immediate recall: verbal or visual	Learning/encoding of new information	Logical or paragraph memory; list learning tasks (e.g., California Verbal Learning); Paired Associate Verbal Learning Test; pattern recall; Rey-Osterreith Complex Figure Test; picture memory
Delayed recall: verbal or visual	Recall of previously learned information	Logical or paragraph memory; list learning tasks (e.g., California Verbal Learning); Paired Associate Verbal Learning Test; pattern recall; Rey-Osterreith Complex Figure Test; picture memory
Recognition: verbal or visual	Ability to accurately recognize learned information (in the case of source monitoring, identifying the context in which the information was learned)	Logical or paragraph memory; list learning tasks (e.g., California Verbal Learning); Paired Associate Verbal Learning Test; pattern recall; Rey-Osterreith Complex Figure Test; picture memory

Results

Effects of breakfast compared with no breakfast

A total of 34 studies met the criteria for examination of the acute impact of consuming breakfast on cognition in healthy adults. A tally of studies according to cognitive domain and findings is found in **Table 2**. In addition, a number of studies that were included had quite small sample sizes (<20 participants). We also examined studies with sample sizes >20 participants and have included the results of those studies in **Table 3**. Results are described by domain of cognitive function below.

Attention/processing speed

Attentional capacity. Studies measuring attentional capacity typically used a digit span task, which asks the subject to repeat a string of numbers. Of the 6 studies examining the impact of breakfast on attentional capacity, 4 demonstrated no significant effects (14–17), whereas 2 demonstrated an advantage from breakfast (18, 19). In the studies that demonstrated no effect of breakfast, postprandial cognitive testing began within 10 min of caloric intake. In contrast, studies that showed a positive effect commenced postprandial testing ≥15 min later, suggesting a possible influence of timing of test administration on this effect.

Vigilance/focus. Vigilance was assessed in 8 studies with the use of a number of different measures. Most common was a version of a continuous performance test in which subjects are presented with a series of individual digits or letters on a screen and must respond to a target digit or letter. Another version of this type of test is the Bakan test, in which subjects view a computer screen presenting digits, one at a time, and are asked to press a key upon seeing 3 consecutive even or 3 consecutive odd digits. Whereas 5 studies that examined vigilance demonstrated no significant effects (15, 20–23), 3 exhibited better performance after breakfast than after no-breakfast (24–26) conditions. No test emerged as best able to detect differences, and methodologic variability in study designs precludes pattern detection for these disparate findings.

Psychomotor/processing speed. The most commonly investigated subdomain of attention, psychomotor/processing speed, was included in 10 studies. Most studies did not demonstrate an overall effect of breakfast on simple or

TABLE 2 Effects of breakfast compared with no breakfast on cognitive function in healthy adults[1]

Cognitive domain	Total studies,[2] *n*	Total test occurrences,[3] *n*	Outcome of test occurrences[4]: Advantage of breakfast	Equivocal	Disadvantage of breakfast
Attention and processing					
Attentional capacity	6	6	2 (18, 19)	4 (14–17)	0
Vigilance	8	8	3 (24–26)	5 (15, 20–23)	0
Processing speed	10	11	3 (19, 20, 30)	6 (16, 21, 24, 27–29)	2 (31)*
Executive functions					
Reasoning/planning	2	2	0	2 (32, 33)	0
Inhibitory control	4	4	1 (35)	1 (27)	2 (31, 34)
Working memory	14	17	9 (18, 19, 23, 27, 30, 35–38)	8 (14, 16, 27, 28, 31, 34, 37, 38)	0
Language					
Semantic processing	1	1	0	1 (33)	0
Verbal fluency	3	3	0	3 (16, 34, 37)	0
Motor					
Gross motor speed	2	2	1 (21)	1 (15)	0
Learning and memory					
Immediate recall	6	6	3 (17, 38, 40)	3 (27, 34, 39)	0
Delayed recall	19	23	16 (14–17, 21, 24, 29, 32–34, 38, 40–43)*	7 (14, 15, 27, 34, 39, 44, 45)	0
Recognition	4	4	3 (17, 38, 46)	1 (27)	0

[1] Findings are presented for 34 different studies. Some studies examined certain subdomains with the use of >1 measure. *Instances in which the same study included >1 test in that domain with the noted result.
[2] Total number of studies that measured the specified subdomain.
[3] Number of times the specified subdomain was measured across studies.
[4] Number of observations for each of the outcomes (references).

choice reaction time (21, 24, 27, 28) or psychomotor speed tasks (16, 29) in healthy adults. Three studies revealed a benefit of breakfast on speeded processing with the use of psychomotor (30) or reaction time (19, 20) tests. Mixed results were seen in one study: no differences emerged between fasting and breakfast conditions on a simple reaction time test, but a negative impact of breakfast was observed on 2 tasks: a rapid visual information processing task and a 4-choice reaction time task (31). Of note, the sample size was small relative to other studies, and the study appeared to have been powered to detect large effects expected from an exercise component of that study. Overall, although a small number of studies that used psychomotor and processing speed tasks showed a benefit of breakfast and one study produced negative impact, the greater proportion demonstrated no significant effects.

Executive functions

Reasoning/planning. Two studies examined the effects of breakfast on reasoning/planning with the use of the Graduate and Managerial Assessment Test of Abstract Reasoning (32) and a logical reasoning task (33); neither study detected any difference between breakfast and no-breakfast conditions. Although there is no evidence that reasoning/planning is affected by the consumption of breakfast, the small number of studies that examined this subdomain of executive function is noted. Future work in this domain may prove beneficial to better discern effects.

Inhibitory control. Inhibitory control was assessed in 4 total studies. Three studies used the Stroop Color and Word Test, which requires speeded inhibition of a prepotent response in favor of a response requiring greater cognitive processing. Of these studies, one demonstrated faster performance (34), although this occurred in the context of reduced accuracy. Decreased accuracy was also observed in a study that did not examine speed of response (31), whereas another found no difference between conditions (27). In contrast, one study demonstrated an advantage of breakfast on a computerized reaction time measure that included an inhibitory control component (35). In short, equivocal or negative findings have been elicited with the use of the Stroop task, but inhibitory control has not been well studied. Other tasks of this ability may yield different effects.

Working memory. Fourteen studies examined working memory, with some studies using more than a single task of this subdomain, for a total assessment of 17 occurrences of working memory. Although the tasks used to examine working memory are highly disparate, all included a component that required the subject to manipulate complex cognitive operations in temporary cognitive storage (e.g., mental calculations, reversing a string of numbers, etc.). Nine of these studies demonstrated a benefit of breakfast on a number of tasks, including an experimental spatial working memory task (23), a trigram recall task (36), Serial 3s and 7s (27, 30, 37), the Corsi block tapping test (18, 38), and the Combi test (19, 35). However, 8 studies found no differences between breakfast and no-breakfast conditions on the Corsi block tapping test (27), Serial 3s and 7s (37, 38), computerized repeated digits or N-back test (28, 31), Mental Control (16), backward digit span (14), or on the Paced Auditory Serial Addition Task (34). Given the large variety of tasks used, and that the same tests in different studies showed both a benefit and

TABLE 3 Effects of breakfast compared with no breakfast in healthy adults in studies with >20 participants[1]

Cognitive domain	Total studies,[2] *n*	Total test occurrences,[3] *n*	Outcome of test occurrences[4]: Advantage of breakfast	Equivocal	Disadvantage of breakfast
Attention and processing					
Attentional capacity	6	6	1 (18)	3 (14, 16, 17)	0
Vigilance	8	8	2 (24, 25)	1 (23)	0
Processing speed	10	11	1 (30)	5 (16, 24, 27–29)	2 (31)*
Executive functions					
Reasoning/planning	2	2	0	2 (32, 33)	0
Inhibitory control	4	4	0	1 (27)	1 (34)
Working memory	14	17	7 (18, 23, 27, 30, 36, 37, 38)	7 (14, 16, 27, 28, 34, 37, 38)	0
Language					
Semantic processing	1	1	0	1 (33)	0
Verbal fluency	3	3	0	3 (16, 34, 37)	0
Motor					
Gross motor speed	0	0	0	0	0
Learning and memory					
Immediate recall	6	6	3 (17, 38, 40)	3 (27, 34, 39)	0
Delayed recall	18	20	14 (14, 16, 17, 24, 29, 33–34, 38, 40–43)*	6 (14, 27, 34, 39, 44, 45)	0
Recognition	4	4	3 (17, 38, 46)	1 (27)	0

[1] Findings are presented for 27 different studies. Some studies examined subdomains with the use of >1 measure. *Instances in which the same study included >1 test in that domain with the noted result.
[2] Total number of studies that measured the specified subdomain.
[3] Number of times the specified subdomain was measured across studies.
[4] Number of observations for each of the outcomes (references).

equivalence, it is difficult to determine whether breakfast shows a benefit in this domain; however, it is notable that no studies demonstrated a disadvantage.

Language

Language abilities were examined in 4 studies. Results were largely equivocal between breakfast and no-breakfast conditions. Specifically, 3 studies examined verbal fluency, which asks subjects to generate words quickly beginning with a given letter (phonemic fluency) or fitting a designated category (semantic fluency) in a specified amount of time. Two studies demonstrated no difference between glucose and placebo beverages on phonemic (34) or semantic (16) fluency, whereas another found a trend toward improvement after a glucose beverage (37). One study found that there were no effects of consuming a cereal bar for breakfast compared with fasting on a task of semantic processing (33). Overall, a substantial alteration in language task performance was not observed after breakfast, although little work has been conducted that compares language in studies that used ecologically valid breakfasts.

Motor functions

Two studies assessed motor abilities with the use of a finger tapping test, which examines how quickly an individual can tap 1 or 2 fingers. One study found no differences in breakfast compared with no-breakfast conditions (15), whereas the other demonstrated improvement (21). The timing of assessment may have played a role in the findings for this outcome, because the study finding no positive effects of breakfast began cognitive testing 10 min after breakfast (15), whereas the other commenced testing 30 min later; however, to our knowledge, too few studies have examined this domain to make a conclusive statement regarding the role of timing.

Learning and memory

Immediate recall. Six studies examined immediate recall, with some studies that used multiple measures. Although tasks differ, all have a common requirement to demonstrate that new information has been encoded (e.g., repeating a word list or story immediately after it is read). Of these studies, 3 found no effects of breakfast on immediate recall for verbal list learning tasks (27, 34, 39). In contrast, 3 studies demonstrated a benefit of breakfast on immediate recall for verbal list learning, including 3 studies in healthy individuals (17, 38, 40). The variability of tasks used and the similar number of studies showing benefits and equivalence prevent a conclusion regarding the effects of breakfast on immediate memory.

Delayed recall. By far, the most frequently studied subdomain of cognition is delayed recall, again with several studies that used >1 measure; specifically, 19 studies were identified, with 23 occurrences of delayed-recall measurement. Although several different types of tasks were used, all involved a component in which the subject reproduced newly learned information (verbal or visual), typically learned ~15–45 min earlier. Fifteen studies demonstrated a benefit of breakfast on tasks of delayed recall, including verbal list recall (14, 16, 17, 21, 24, 32, 33, 38, 40–43), story/paragraph recall (15, 29, 34), and selective reminding (15). One study demonstrated that subjects performed spatial and verbal memory tasks more quickly after eating breakfast, but showed no difference in accuracy compared with the fasting condition (44). In contrast, breakfast was not related to performance on delayed recall for 8 studies, including verbal list learning tasks (27, 34, 39, 45) or the recall of the Rey Complex Figure Test (14, 15). In summary, although not fully consistent, the preponderance of work examining delayed recall tasks shows a benefit of eating breakfast.

Recognition. Four studies examining recognition memory, or ability to recognize a piece of newly learned information after a delay, were found in this literature review. Better performance on tasks of recognition for word lists was demonstrated in 3 studies (17, 38, 46). Another study showed no effect of breakfast on word recognition accuracy, but subjects' speed of recognition was substantially faster after a glucose beverage than with a placebo (27). Thus, although this subdomain of memory has been less-frequently examined than recall, the evidence suggests a possible benefit of breakfast for recognition memory.

Effects of breakfast composition

A total of 12 studies compared cognition in healthy adults after breakfasts with different macronutrient composition, or manipulations to contrast high- and low-GL or -GI conditions. Given that far fewer studies have examined these questions, results are presented according to the larger domains, but not separated by subdomain. The language domain is omitted, because it was not addressed in any of these studies. This literature is highly disparate in sample characteristics, comparison conditions/meals used, and findings; greater detail than can be provided in the below text can be found in **Table 4**.

Attention/processing speed

Comparisons of protein, carbohydrate, and fat manipulations on attentional functions in healthy adults were examined in 4 studies. One study found that performance improved over time on a complex vigilance task with fat intake compared with placebo, but no such differences emerged for carbohydrate or protein. This study demonstrated similar benefits of fat and carbohydrate on psychomotor speed, an effect that was not observed for the protein meal (29). Another study found that choice reaction decision time and error rate were best after consumption of fat compared with carbohydrate and protein (35). Work from the same research team demonstrated that performance on a vigilance measure combining working memory and peripheral attention was most accurate after a high-protein meal compared with balanced and high-carbohydrate meals (19). In the same study, comparisons of choice reaction time showed a quicker decision time after a high protein meal, but no accuracy differences (19). No effects of macronutrient content were observed on a peripheral attention test (carbohydrate compared with protein compared with fat) (35), the Bakan test (carbohydrate compared with fat) (21), or a simple reaction time test (carbohydrate compared with protein compared with fat) (21, 35). Two studies compared low- with high-GI breakfasts; these studies, both conducted in healthy older adults, showed a benefit of the low-GI breakfast for a test of vigilance requiring selective attention (47, 48). A breakfast manipulation contrasting slowly and rapidly available glucose in healthy young adults showed no difference for vigilance or reaction time (24). Thus, although the findings are not entirely consistent, it appears that, compared with high-carbohydrate conditions, more balanced meals with a lower GI, higher protein, and higher fat could have a positive impact on attention tests. However, there is variability in the samples examined, the experimental manipulations, and the measures used to test cognition, which may contribute to differential findings. More work is needed to replicate findings within specific types of breakfast manipulations, as well as comparisons across samples targeting different populations, to determine whether age or associated factors (e.g., altered glucoregulation) underlie disparate findings across groups.

Executive functions

Results for the effects of meal composition on executive functions are mixed, in part due to the variety of comparisons made, the tests used, and the functions assessed. Three studies examined the effects of macronutrient composition on working memory tests, with different comparisons and disparate findings. One study demonstrated an advantage after protein and poorer performance after carbohydrate (20). In a different study, greater accuracy but slower speed was observed in high-carbohydrate compared with balanced carbohydrate/protein and high-protein conditions (19), although a different study from that same laboratory showed that performance was better in a fat condition than in carbohydrate and protein conditions (35). An examination of executive functions with the use of manipulations of GI was conducted in one study, which found that working memory performance was better after a low-GI than a high-GI breakfast (48). The executive function domain has been infrequently examined, and different findings in the context of distinct methodologies preclude conclusions.

Motor functions

One study examined the effects of macronutrient manipulations on motor function in healthy adults, and found that there were no effects of varying fat and carbohydrate content on performance on a 2-finger tapping test (21). Thus, the current evidence does not suggest an effect of breakfast composition on motor functions, but, to date, research in this domain is limited.

Learning and memory

Six studies examined the impact of breakfast composition on learning and memory in healthy adults. Four studies investigated the effects of macronutrient composition on memory. One study (29) found no effect of breakfast composition (carbohydrate compared with protein compared with fat) on delayed recall of a paragraph; less forgetting was observed after the protein beverage than with placebo, but this was not observed after the carbohydrate or fat beverage. For word list recall, this same study demonstrated

TABLE 4 Studies examining the cognitive effects of breakfast composition[1]

Reference	Design	Sample	Conditions	Cognitive measures and timing	Reported results
19	Randomized crossover; CHO-to-PRO ratio	Healthy; *n* = 15; age 26.3 y; 100% M	*1)* 4:1: 8.4 g glucose, 33.7 g maltodextrin, 8.4 g rice starch, 18.9 g milk PRO, 2.1 g dried chicken, 150 mL water *2)* 1:1: 5.3 g glucose, 21.0 g maltodextrin, 5.3 g rice starch, 47.3 g milk PRO, 5.3 g dried chicken, 200 mL water *3)* 1:4: 2.1 g glucose, 8.4 g maltodextrin, 2.1 g rice starch, 75.8 g milk PRO, 8.4 g dried chicken, 250 mL water	Baseline, then every 15 min to 210 min Choice RT, Combi test, multitask test	*1)* Immediate benefit of high CHO on attention *2)* Better choice RT over time with ratio of higher PRO or balanced PRO to CHO *3)* Better choice RT, short-term memory, attention, and RT over time with ratio of higher PRO or balanced PRO to CHO
20	Randomized crossover; glucose vs. PRO vs. fat vs. placebo	Healthy; *n* = 18; age 19 y; 72.2% F	*1)* Placebo: 290 mL water, 10 mL lemon juice, 2 g aspartame *2)* Glucose: 260 mL water, 40 g glucose dextrose powder, 10 mL lemon juice *3)* Fat: 249 mL water, 10 mL lemon juice, 2 g aspartame, 16 g Pura vegetable oil *4)* PRO: 260 mL water, 10 mL lemon juice, 2 g aspartame, 40 g Casilan 90% PRO powder	Baseline and 15 and 60 min Verbal list learning with concurrent frontomotor task (fist-chop-slap), picture memory, simple RT, choice RT, digit vigilance, numeric working memory	*1)* Better immediate word recall and numeric working memory accuracy with PRO than with placebo *2)* Impaired working memory with glucose compared with placebo
21	Randomized crossover; varying fat and CHO content	Healthy; *n* = 16; age 26.1 y; 87.5% F	*1)* Fasting *2)* Low fat/high CHO: 18.4 g fat, 98.7 g CHO, 15.2 g PRO *3)* Med fat/med CHO: 29.3 g fat, 74.8 g CHO, 13.8 g PRO *4)* High fat/low CHO: 38.5 g fat, 56.2 g CHO, 14.5 g PRO	Baseline and 30, 90, and 150 min Bakan test, 2-finger tapping test, free recall task, simple RT	No differences between conditions
29	Randomized crossover; PRO vs. CHO vs. fat	Healthy; *n* = 22; age 71.2 y; 50% F	*1)* Placebo: 290 mL water, 10 mL lemon juice, 23.7 mg saccharin *2)* CHO: 260 mL water, 10 mL lemon juice, 50 g glucose *3)* PRO: 260 mL water, 10 mL lemon juice, 50.5 g whey PRO isolate, 23.7 mg saccharin *4)* Fat: 248.9 mL water, 10 mL lemon juice, 41.1 g microlipid, 23.7 mg saccharin	15 and 60 min Verbal list learning, paragraph recall, trail-making test, experimental attention task	*1)* CHO improved or tended to improve trials at 15 and 60 min in men *2)* CHO and fat improved or tended to improve trials at 15 and 60 min in those with poor baseline *3)* Fat improved or tended to improve attention at 60 min *4)* PRO reduced rate of forgetting on paragraph recall at 15 min
35	Randomized crossover; CHO vs. PRO vs. fat	Healthy; *n* = 15; age 26.5 y; 100% M	*1)* CHO: 10.5 g glucose, 84.2 g maltodextrin, 10.5 g rice starch, 150 mL water *2)* PRO: 94.7 g milk PRO, 10.5 g dried chicken, 250 mL water *3)* Fat: 15 g soybean oil, 15 g palm oil, 31.5 g double cream, 150 mL water	Every 15 min to 180 min Simple and choice RT, Combi test	*1)* Fewer errors for choice RT after CHO vs. PRO *2)* Greater accuracy and efficiency in peripheral attention after PRO vs. CHO *3)* Fat superior to PRO and CHO for both

(Continued)

TABLE 4 (*Continued*)

Reference	Design	Sample	Conditions	Cognitive measures and timing	Reported results
41	Nonrandomized crossover; glucose vs. PRO	Healthy; *n* = 20; age 22 y; 50% F	*1)* Placebo: 240 mL water, 3 mg saccharin *2)* Glucose: 240 mL water, 50 g glucose *3)* PRO: 240 mL water, 50 g PRO	Baseline and 60 min Verbal paired associates, story memory	Greater improvement for glucose than with PRO
47	Randomized crossover; high vs. low GI	Healthy; *n* = 40; age 59 y; 50% F	*1)* High GI: 50 g glucose bolus *2)* Low GI: 50 g glucose sipping	35, 90, 120, 150, and 170 min Experimental oral working memory task, experimental visual selective attention task	Controlling for GT, better selective attention (170 min) after low- than after high-GI simulation.
48	Randomized crossover; low sustained glucose vs. high GI	Healthy; *n* = 40; age 62.9 y; 70% F	*1)* High GI: 125 g white wheat bread *2)* Low sustained glucose: 179 g guar gum–enriched white wheat bread, providing 50 g available starch	75, 90, 120, 135, 165, 180, 210, and 225 min Experimental oral working memory task, experimental visual selective attention task	Low sustained glucose superior to high GI in selective attention late postprandial (75–225 min)
49	Parallel arms (randomized); low vs. high GI	Healthy; *n* = 106; age 21.1 y; 100% F	*1)* Low GI: plain biscuit cereal, 68.5 g CHO, 17.6 g fat, 6.6 g PRO; GI = 42.3; 15.8 g SAG, 39.5 g RAG *2)* High GI: cereal bar, 62.6 g CHO, 17.7 g fat, 7.3 g PRO; GI = 65.9; 0.1 g SAG, 42.3 g RAG	30, 90, 150, and 210 min List learning	Better verbal memory with low-GI breakfast at 150 and 210 min
50	Randomized crossover; low vs. high GI	T2DM; *n* = 21; age 65 y; 52.4% F	*1)* Placebo: 250 mL water *2)* Low GI: 55.8 g pasta, 37.5 g cheese, 123.8 g tomato sauce *3)* High GI: 98.6 g bread, 37.5 g cheese, 123.8 g tomato sauce	15 min List learning, paragraph recall, verbal paired associates, digit span, trail-making, Test of Everyday Attention	High GI worse than low GI for list learning, logical memory recall, working memory, executive function, and auditory selective attention
51	Randomized crossover; low vs. high GL	T2DM; *n* = 34; age 58.6 y; 52.9% F	*1)* Fasting: 438 g water *2)* Low GL: 37.3 g CHO, 9.3 g fat, 20.9 g PRO, 12 GL *3)* High GL: 75 g CHO, 0 g fat, 0 g PRO, 71 GL	30 and 120 min Visual spatial learning, visual verbal learning, Corsi block tapping, Tower of Hanoi, grooved peg-board, psychomotor test, source monitoring, paragraph recall	No effects, high vs. low GI
52	Randomized crossover; low vs. high GL	Impaired GT and T2DM; *n* = 99; age 38.4 y; 83.8% F	*1)* Fasting: 438 g water *2)* Low GL: 37.3 g CHO, 9.3 g fat, 20.9 g PRO, 12 GL *3)* High GL: 75 g CHO, 0 g fat, 0 g PRO, 71 GL	30 and 120 min Visual verbal learning	No effects, high vs. low GI
53	Randomized crossover; low vs. high GL	Healthy and impaired GT; *n* = 65; age 37.6 y; 100% F	*1)* Fasting: 438 g water *2)* Low GL: 37.3 g CHO, 9.3 g fat, 20.9 g PRO, 12 GL *3)* High GL: 75 g CHO, 0 g fat, 0 g PRO, 71 GL	30 and 120 min Visual spatial learning, visual verbal learning, Corsi block tapping, Tower of Hanoi, grooved peg-board, psychomotor test, word recognition	Low-GL breakfast improved verbal memory impairment in those with impaired GT and high waist circumference

(*Continued*)

TABLE 4 (*Continued*)

Reference	Design	Sample	Conditions	Cognitive measures and timing	Reported results
54	Parallel arms (randomized); varying CHO and fiber content	Healthy; *n* = 168; age 20.4 y; 100% F	*1)* Low CHO/low fiber: 15.10 g CHO, 1.46 g fiber, 0.34 g fat, 4.62 g PRO *2)* Low CHO/med fiber: 14.45 g CHO, 6.09 g fiber, 0.94 g fat, 6.03 g PRO *3)* Med CHO/low fiber: 30.44 g CHO, 1.56 g fiber, 0.59 g fat, 8.83 g PRO *4)* Med CHO/med fiber: 29.79 g CHO, 6.19 g fiber, 1.10 g fat, 10.24 g PRO *5)* Med CHO/high fiber: 30.25 g CHO, 13.05 g fiber, 2 g fat, 12.45 g PRO *6)* High CHO/low fiber: 49.84 g CHO, 1.44 g fiber, 0.58 g fat, 10.44 g PRO *7)* High CHO/med fiber: 50.85 g CHO, 6.13 g fiber, 1.20 g fat, 12.01 g PRO *8)* High CHO/high fiber: 49.65 g CHO, 12.93 g fiber, 2.08 g fat, 14.06 g PRO	30 and 90 min Word list memory, rapid information processing task (vigilance), RT, and choice RT	*1)* Higher CHO related to faster RT at the later session; fastest with 1.5 g fiber *2)* Poor GT: high CHO and fiber related to poorer verbal memory
55	Parallel arms (randomized); varying CHO, fat, and PRO content	Healthy; *n* = 189; age 20.4 y; 100% F	*1)* Low CHO/low fat/low PRO: 24.4 g CHO, 1.1 g fat, 1.7 g PRO, 3.3 g fiber *2)* High CHO/low fat/low PRO: 59.4 g CHO, 1.1 g fat, 1.7 g PRO, 3.3 g fiber *3)* Low CHO/high fat/low PRO: 24.6 g CHO, 16.5 g fat, 1.7 g PRO, 3.2 g fiber *4)* High CHO/high fat/low PRO: 59.6 g CHO, 16.5 g fat, 1.7 g PRO, 3.2 g *5)* Low CHO/low fat/high PRO: 24.2 g CHO, 1.0 g fat, 9.8 g PRO, 3.2 g fiber *6)* High CHO/low fat/high PRO: 59.2 g CHO, 1.0 g fat, 9.8 PRO, 3.2 g fiber *7)* Low CHO/high fat/high PRO: 24.2 g CHO, 16.4 g fat, 9.9 g PRO, 3.2 g fiber *8)* High CHO/high fat/high PRO: 59.4 g CHO, 16.4 g fat, 9.8 g PRO, 3.2 g fiber	30, 75, and 120 min; *1)* list learning; *2)* rapid information processing task (vigilance); *3)* RT and choice RT	*1)* In individuals with better GT, high-GL breakfast related to faster reaction times and more correct responses in vigilance task *2)* In individuals with better GT, better memory was observed with low amounts of PRO

[1] All results presented were significant unless a trend was noted. CHO, carbohydrate; GI, glycemic index; GL, glycemic load; GT, glucose tolerance; Med, medium; PRO, protein; RAG, rapidly available glucose; RT, reaction time; SAG, slowly available glucose; T2DM, type 2 diabetes mellitus.

poorer performance after fat ingestion in the entire sample than with placebo, whereas carbohydrate (glucose beverage) was related to worse performance than placebo in men only; there was no effect of drink (carbohydrate compared with protein compared with fat) on list learning (29). A comparison of glucose and protein beverages demonstrated that glucose consumption was related to better delayed memory performance than was a protein beverage (41). In contrast, a study comparing protein, fat, and carbohydrate to placebo beverages demonstrated a benefit of protein on immediate word recall compared with placebo; this was not observed after fat or carbohydrate consumption (20). Another study found no effect of meal type on free recall of a verbal list learning test that used meals of varying fat and carbohydrate content (21). Two studies that compared the effects of glycemic manipulation on memory performance were conducted. These demonstrated a benefit of a low GI or slowly available glucose meals compared with high-GI or rapidly available meals for immediate and delayed recall of a word list (24, 49). Thus, there is slightly more evidence to support a benefit of protein or a lower-GI breakfast, although the available research on the effects of breakfast composition on learning and memory is limited and the findings are mixed, with some evidence supporting a benefit of carbohydrate over protein. Given the heterogeneity of the methodology and findings in learning and memory, as well as in other cognitive domains, it is difficult to draw conclusions. It is possible that a closer examination of the differences in glucoregulation will elucidate findings.

Differences in glucoregulation. Whereas many of the studies in this literature review examined peripheral glucose response in the context of cognition, a smaller number have taken differences in glucoregulation into account in analyses. With the use of a variety of different methodologies, a total of 8 studies examined the effects of differences in glucoregulation on cognitive response to breakfast and breakfast composition. These are discussed below.

Two studies examined the effects of breakfast and breakfast composition in a sample composed completely of individuals with type 2 diabetes mellitus (T2DM) (50, 56). One study (56) compared fasting with fed (bagel and grape juice) conditions. Although this protocol elicited equivocal results on a task of psychomotor speed, learning and memory patterns suggested an initial benefit of breakfast followed by impaired performance (56). The other study compared fasting, high-GI, and low-GI conditions (50) in individuals with T2DM. This study demonstrated that, relative to a fasting condition, a breakfast condition yielded better attentional capacity, but poorer performance in immediate story recall; findings in other domains were equivocal (50). In comparing high- and low-GI conditions, low GI showed better attentional capacity, improvement over time on a complex sequencing task, and superior immediate and delayed recall of a word list; no effects of the GI manipulation were observed for other tasks, including a divided attention/working memory task, immediate paragraph recall, and verbal paired associates (50). Thus, for individuals with T2DM, evidence supports that breakfast benefits aspects of cognition, but, particularly over time, a low-GI breakfast may yield greater benefit for these individuals.

Three studies compared healthy samples with individuals with T2DM and/or impaired glucose tolerance with the use of paradigms that involved fasting and high-GL, and low-GL conditions (51–53). In one study, the fasting condition elicited poorer verbal recall performance in individuals with T2DM than in those with normal glucose tolerance; this difference was not observed in the breakfast condition (51). In another study from the same laboratory (52), individuals with impaired glucose tolerance and a high waist circumference demonstrated impaired learning in the fasting and high-GL conditions; this pattern was not observed after the low-GL breakfast. In addition, pegboard completion time was slower in the fasting condition than in both the low- and high-GL conditions, suggesting an overall benefit of breakfast for fine motor speed, irrespective of glucoregulation status. This study also found poorer delayed spatial memory after the high-GL breakfast in those with impaired glucose tolerance and high waist circumference than in individuals with normal glucose tolerance and low waist circumference; this pattern was not observed in the low-GL or placebo conditions. These 3 studies identified no main effects of breakfast or interactions between diabetes status and breakfast on performance for reasoning/planning (51, 53), working memory (51, 53), immediate recall of a word list (51, 53), paragraph recall (53), word recognition (51), spatial memory (51, 53), fine-motor coordination (51, 53), or source monitoring (52).These comparisons support a possible cognitive benefit of breakfast, particularly a low-GL breakfast, in individuals with impaired glucoregulation; however, although breakfast facilitated motor speed across glucoregulation groups, these studies suggest that breakfast and breakfast composition may have less impact in those with healthy glucoregulation compared with those with T2DM.

Whereas most studies examining glucoregulatory function in the context of breakfast effects on cognition included samples with clinically impaired glucoregulation, 2 studies used healthy young adult samples split into groups with "poorer" and "better" glucoregulation (54, 55). One study demonstrated that those with better glucoregulation recalled more words in a low-protein condition than did those in a high-protein condition and individuals with poorer glucoregulation consuming the same amount of protein; the amount of protein consumed did not influence the recall of those with poorer glucoregulation (54). In another study from the same authors, the amount of carbohydrate did not influence memory for those with better glucoregulation; however, in those with poorer glucoregulation, less forgetting was observed after a low-carbohydrate meal. In addition, in those with poorer glucoregulation, performance was worse after faster glucose release than with slower glucose release, although glucose release did not influence memory in those with better glucose tolerance (55). These studies suggest that even for otherwise healthy individuals, a breakfast that is lower in carbohydrate could benefit those with poorer glucoregulation; however, lower protein may be beneficial for those with excellent glucoregulatory functions.

However, differences in glucoregulation may be complicated by the aging process, as well as sex differences. One study (34) directly compared younger (mean age = 20.8 y) and older (mean age = 68.5 y) adult age groups. In general, although older participants performed more poorly on most cognitive testing than did the younger group, the cognitive effects of breakfast did not differ between age groups, with one exception. Specifically, older men with good recovery of peripheral blood glucose to baseline performed better in a glucose ingestion condition compared with placebo on a list learning/memory task. In contrast, younger men with poor recovery demonstrated better scores on this test in the glucose than in the placebo condition, whereas the young men with good recovery demonstrated poorer performance. No significant differences in performance were seen for older men with poor recovery, or older or younger women with good or poor recovery. Replication is needed to determine whether these findings hold; however, this study highlights the potential interactive effects of age and sex with glucoregulation.

When considered as a whole, the findings suggest that, not only for those with impaired fasting glucose, but also for healthy persons, differences in glucoregulation may lead to different patterns of performance. Those with poorer glucoregulation may show cognitive benefits from low-GL/low-carbohydrate conditions; however, it is possible that meals characterized by lower protein and fat content with higher carbohydrate and faster glucose release could optimize cognition in those with excellent glucoregulation. Although more work is needed to determine the possible interactive effects of age and sex with glucoregulation, given that such differences in glucoregulation have been found to affect cognition even in healthy samples, it must be considered whether, if not taken into account, they could mask true postprandial cognitive effects in several of the studies reviewed here.

Discussion

This review integrates findings from 38 studies that examined the cognitive impact of breakfast, and 16 studies that examined the effects of breakfast composition in adults, 8 of which were conducted in samples that allowed examination of the effects of glucoregulation. Results suggest that, for healthy individuals, there is an advantage of consuming breakfast for memory (particularly delayed recall). In contrast, no definitive conclusions can be drawn in regard to the impact of breakfast type on cognition for healthy adults. For individuals with impaired glucoregulation, a possible cognitive benefit of breakfast, particularly a low-GL breakfast, has been detected. These findings highlight the importance of considering differences in glucoregulation in research designs that examine these questions.

Overall, there is a large quantity of studies that have examined the cognitive impact of caloric intake after a fast of ≥8 h. The quality of much of this work, particularly studies conducted in recent years, is good; however, methodologic differences across studies appear to lead to inconsistency in findings. Moreover, many of these studies have been conducted in healthy young adult populations, which could limit generalizability. Despite the limitations of this literature, when examined as a whole, patterns of performance emerge. In contrast with a recent review of fasting cognition (9), in which no significant impact of breaking a fast was detected, the expanded literature reviewed here shows that the majority of studies that examine this question in healthy adults show positive effects of breakfast on delayed recall. Most studies that examined recognition memory also showed a benefit, although far fewer examined this variable. Evidence is more equivocal for the cognitive domains of attention and executive function. Motor speed has been examined infrequently, but also yields equivocal findings. Language functions, also rarely studied, have not shown any significant impact of breakfast. Differences between the current review and the earlier work (9) include the fact that the current review examined only research designs incorporating ≥8 h of fasting, whereas the previous review included several studies with more abbreviated fasting paradigms. In addition, our broad definition of breakfast appears to have led to a review of a larger number of studies. Although inclusion of laboratory-developed meals may have contributed to more studies' showing a benefit of breakfast, we undertook to examine findings from ecologically valid breakfasts separately from the overall literature presented, and found that these did not alter the proportion of positive compared with equivocal study outcomes for any cognitive domain. A review of the expanded literature appears to have been of benefit in detecting this pattern.

In contrast, far fewer studies of breakfast composition have been conducted. The quality of this body of work is generally quite good, but methodologies (e.g., meal conditions, tests used, and timing of administration) vary considerably across studies. The studies also frequently address this question in samples that represent special populations (e.g., older adults), which is important, because these populations may show different responses; however, in the context of so few studies, the examination of special groups is yet another methodologic difference that limits overall generalizability. In comparison with the recent review conducted by Edefonti et al. (11), our broader definition of breakfast yielded a larger selection of studies to examine (16 compared with 4). Unfortunately, because of disparate methodology, the larger number of studies did not lead to a greater ability to detect a pattern regarding cognitive effects of any specific macronutrient ratio, GL, or GI in healthy adults. Similarly, our aim to examine work conducted in adults apart from research in children did not result in substantially different conclusions from previous work. However, given that the frontal lobes, which are critical to many aspects of higher cognition, are not yet fully developed in the child and adolescent brain (12), we believe that the distinction is nonetheless important.

Whereas some have suggested that a postprandial rise in blood glucose underlies better cognitive performance (10), others indicate that lower postprandial glycemic response appears to benefit cognition (11). We integrated these interpretations by noting the importance of differences in glucoregulatory function. The subset of studies specifically examining glucoregulation with the use of cohorts with T2DM or impaired glucose tolerance often found a cognitive benefit of breakfast (compared with no breakfast) for attention, speed, and memory processes. For these individuals, it appears that a breakfast with a lower GI or GL may better facilitate cognition than a high-GI or -GL breakfast (50–53). However, even work within healthy cohorts may benefit from a consideration of differences in glucoregulation. Evidence suggests that different patterns emerge in healthy persons, such that a higher postprandial glucose response may benefit aspects of cognition in individuals with excellent glucoregulation (54). Studies of cognitive response to breakfast within healthy persons may be missing effects that could be teased apart with consideration of these individual differences.

The differentiation in postprandial enhancement of some cognitive skills compared with others warrants brief discussion, as well. Few studies, to our knowledge, have examined functional neuroimaging in the context of food consumption. However, different neuroanatomical regions have long been hypothesized and supported in connection with the cognitive tasks and domains examined here (12). For example, consolidation of memory, the primary function assessed in delayed recall tasks, is associated with medial temporal regions of the brain, including the hippocampal formation (57). The hippocampal formation is known to be vulnerable to hypoglycemia, causing structural damage in individuals with clinically significant hypoglycemia (58). It is possible that better memory performance after breakfast reflects the resolution of lowered fasting glucose concentrations that are affecting hippocampal function. In contrast, higher order executive functions have been more often linked to the brain's frontal systems and the prefrontal cortex in particular, whereas attentional skills are linked to limbic, frontal, and parietal association cortices (57). Linked to different neuroanatomical substrates, executive and attentional functions would not necessarily be expected to show the same response to food intake demonstrated by memory indexes.

Although a cognitive benefit of breakfast would appear to have clear potential implications, the magnitude of effects observed is small, which may limit functional impact. Moreover, although work with impaired glucoregulation cohorts suggests that a low-GI or -GL breakfast may benefit cognition, no firm conclusions may yet be drawn in regard to the effects of breakfast composition on cognition in healthy adults. At present, it appears that the type of breakfast consumed by a healthy adult does not matter as much as simply consuming some type of breakfast.

There are a number of limitations of this review. For example, we report here on adults in general, spanning a wide range of ages. In the course of preparing this review, we undertook to examine studies of older adults (≥50 y of age) separately from studies of younger adults, and noted that the removal of this group did not yield greater consistency in findings. However, given work suggesting that younger and older adults may show different postprandial cognitive responses in the context of glucoregulatory differences (34), age is a variable that warrants further investigation. Future research is needed to directly examine the effects of breakfast on cognition across the lifespan. In addition, most of the studies included in this review were conducted in the Western world (e.g., in the United Kingdom, United States, and Canada). The studies reviewed listed by country of origin can be found in **Table 5**. The over-representation of Western cultures could limit generalizability because of the impact of cultural differences on cognitive testing and measurement (59). Future research should examine the impact of breakfast on cognition in developing nations and the influence of cultural differences in cognitive testing on these effects.

Other limitations may be found in the state of the literature reviewed. For example, in addition to differences in glucoregulation, a number of other individual differences that could play a role in the relation between breakfast consumption and cognition, such as usual frequency of breakfast, have been infrequently examined. Moreover, this review shows that there is very little evidence to support negative cognitive effects of eating breakfast; even for domains demonstrating inconsistent effects, most studies show either equivocal findings or a positive impact. This suggests that the beneficial effects of breakfast could be present, but of small size. Future work should routinely conduct a priori power analyses for each cognitive measure planned to ensure adequate sample size.

Additional limitations of this literature review involve the heterogeneity of methodologies. For example, a limitation inherent to this research is variability in fasting time. Although only studies with a minimum fasting period of 8 h were included, the amount of time fasting varied among studies (typically 8–12 h of instructed fasting). Because mean amount of time fasting is not typically reported in this literature, actual fasting time could vary not only between studies, but within studies as well; some subjects instructed to discontinue eating after a specified hour may

TABLE 5 List of studies by country of origin

Country	*n*	References
United Kingdom	26	14, 16, 17, 20, 21, 23, 24, 27, 28, 29–33, 36–39, 43–45, 49, 52–56
United States	6	15, 22, 25, 26, 34, 46
Canada	5	29, 40, 42, 50, 51
Sweden	2	47, 48
Switzerland	2	19, 35
Iran	1	41
South Korea	1	18

choose to eat up until that time, whereas others may stop eating well before the cutoff. Another challenge within this literature is the variability of timing of test administration across studies. This factor appears to be critical, as demonstrated in the subdomain of attentional capacity, which showed a difference between studies beginning testing within 10 min after a meal [no effects of breakfast detected (14–17)] compared with studies waiting ≥15 min before commencing with testing [benefit of breakfast detected (18, 19)]. Similarly, lack of consistency in tests used is problematic, with ~70 tests appearing in this literature, several of which were experimental measures or adaptations of standardized measures, with many tests yielding multiple variables (e.g., accuracy, reaction time, etc.). This variability may contribute to conflicting results across studies, because the specific test selection may affect results. For example, within the subdomain of inhibitory control, the Stroop task yielded equivalent (27) or negative (31, 34) effects, but a computerized task requiring inhibition showed a positive impact of breakfast (35). More work is needed in this understudied subdomain to determine the effects of breakfast, but the inconsistencies noted here may speak to the importance of test selection. Synthesis of findings across studies becomes difficult in the context of the fact that so many different variables are being assessed to measure cognition. Greater consistency across research labs could be of tremendous benefit in integrating and deriving meaning from cumulative findings, which would advance the field.

Conclusions

In brief summation, this review consolidated the results of the available literature on the cognitive effects of breakfast and different breakfast types in adults. Results suggest a small advantage to consuming breakfast for memory, especially delayed recall, which is seen across the majority of a large number of studies. Less clear are the potential benefits for attention and executive function, which tend to show either equivocal or positive findings, with very few disadvantages of breakfast demonstrated. Motor function is rarely studied, and no significant effects of breakfast on language function were observed. In regard to breakfast composition, the relatively small number of studies and methodologic differences prevent any conclusive statements for healthy adults. A small subset of studies examining these questions in persons with impaired glucoregulation suggest that a low-GI or -GL breakfast may be of benefit to this group, but the opposite may be true for those with excellent glucoregulation. The importance of considering differences in glucoregulation, even in healthy cohorts, is highlighted. Future work in this area would benefit from a more unified approach to study design (e.g., timing of administration) and efforts to replicate work with greater consistency in test selection.

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