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Morning eating in relation to BMI: energy intake, composition, and timing: NHANES 2005-2010

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ACCEPTANCE

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ABSTRACT

Background: Obesity continues to be one of the largest public health concerns in our nation. The role of eating patterns as a means for weight management has been studied extensively. However, the role of breakfast in weight management is still poorly understood. The purpose of this study was to understand the role of breakfast in weight management by observing the relationships of energy intake and macronutrient composition, specifically protein and fiber, with weight status during early morning and late morning eating occasions.

Methods: Data from two multiple pass 24h dietary recalls from NHANES 2005-2010 were used. N= 4542 non-pregnant, non-lactating participants aged 20-65 y who did not perform shift work and who had a BMI between 18.5 and 60 kg/m^2 were included. Individuals with missing data for any of the variables were excluded. Data were analyzed with SPSS software version 21. Each of the 2 days was divided into four time periods: time period 1 defined as the first intake of the day occurring between 12:00 a.m. and 4:59 a.m., time period 2 defined as the first intake occurring between 5:00 a.m. and 8:59 a.m., time period 3 defined as the first intake occurring between 9:00 a.m. and 11:30 a.m., and time period 4 defined as the first intake occurring after 11:30 a.m. Time period 2 was designated as "early morning intake" and time period 3 was designated as "late morning intake". The other two time periods were designated as energy intake eaten the rest of the day. Energy (kcal), protein (g), and fiber (g) intakes were then calculated for the whole day and for each time period. For early morning and late

morning intake, energy, protein and fiber were also divided into 5 categories. Those reporting no intake (0 kcals) made up the first category and quartiles were calculated for those reporting energy intakes of ≥ 0.1 kcal. Modified quartiles for the late morning period using the quartile cutoffs for the early morning time period were also calculated. Similarly, those reporting no intake (0 grams) made up the first category for protein and fiber and quartiles were calculated for those reporting protein or fiber intakes of ≥ 0.01 g. Estimated energy requirements (EER) were determined using the prediction equations developed by the Institute of Medicine (IOM 2005). To determine energy intake reporting plausibility, reported energy intake as a percent of EER was calculated. Standard classifications were used for weight status based on BMI. Descriptive statistics (median and 95% confidence interval) were computed for all variables. Multinomial logistic regression analysis was performed to determine associations between morning energy intake, protein, and fiber categories and risk for overweight (OW) and obesity (OB) for both early morning and late morning time periods. For the energy intake categories, Model 1 was controlled for race/ethnicity, age, gender, poverty-income ratio (PIR), smoking status, alcohol consumption, physical activity, self-reported chronic disease, daily eating frequency, and the two day morning eating pattern. Model 2 was controlled for all of the covariates in Model 1 plus energy intake before and after morning eating. Model 3 was controlled for all of the covariates in Model 2 plus energy intake reporting plausibility. For the protein and fiber categories, Model 1, 2, and 3 controlled for the same covariates as the energy intake categories and also controlled for reported energy intake during the early or late morning eating occasions. A p-value of <0.05 was considered statistically significant.

Results: For the energy intake categories during the early morning, compared to no morning intake, Model 1 showed a lower risk for OB in Q2, but no other relationships were seen in any of the other quartiles. Similar results were seen in Model 2 where a lower risk for OB in Q2 was present. In Model 3, however, (controlled for energy intake reporting plausibility) the relationship between energy intake in Q2 and a lower risk for OB disappeared and a higher risk for OW and OB became apparent in Q4. For the late morning analysis, Models 1 and 2 were similar in that there was no association between morning energy intake category and weight status, but for Model 3 there was a higher risk for OW and OB in Q2-Q4. When we used the modified late morning quartile cutoffs in the analysis to eliminate potential bias due to the different quartile cutoffs for the early and late morning eating occasions, the higher risk for OW and OB was still present in Q2-Q4 and the ORs were attenuated compared to when the original late morning cutoffs were used. In terms of composition, compared to no morning intake, there were no significant associations seen between early or late morning protein consumption and weight status in any of the models. Additionally, for the early morning analysis of fiber, Models 1 and 2 did not show an association between morning fiber intake category and weight status, but for Model 3 there was a lower risk for OB in Q4. For the late morning analysis, Model 1 showed a higher risk for OW in Q2, but no other relationships were seen in any of the other quartiles. Similar results were seen in Model 2 where a higher risk for OB in Q2 was present. In Model 3, however, this relationship disappeared and no other associations were seen in any of the other quartiles.

Conclusion: In comparison to having no morning intake (i.e., “skipping”) there was an elevated risk for OW and OB when consuming higher amounts of energy during the early morning and moderate to high amounts of energy during the late morning. The risk for OW and OB was higher in the late morning compared to the early morning eating occasions, in part, but not entirely, because of the higher amounts of energy consumed during the later morning in comparison to the early morning. Therefore, higher energy in both early morning and late morning increase the risk for OW and OB. Furthermore, later timing may increase the risk for OW and OB, independent of energy intake the rest of the day, since individuals who ate later also had higher energy intakes in the later morning compared to the early morning. In addition, compared to no morning intake of fiber, having a very high fiber intake in the early morning, but not the late morning, may decrease the risk for OB independent of energy intake and fiber intake the rest of the day. These associations may not be apparent unless energy intake reporting plausibility is taken into account.

MORNING EATING IN RELATION TO BMI: ENERGY INTAKE, COMPOSITION, AND TIMING: NHANES 2005-2010

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ABBREVIATIONS

BMI	Body Mass Index
CI	Confidence Interval
EER	Estimated Energy Requirement
EM	Early Morning
LM	Late Morning
NHANES	National Health and Nutrition Examination Survey
OB	Obese
OR	Odds Ratio
OW	Overweight
Q	Quartile
rEI	Reported Energy Intake
rEI %EER	Reported Energy Intake as a Percent of EER
TEI	Total Energy Intake

CHAPTER I

INTRODUCTION

Obesity continues to be one of the largest public health concerns in our nation and is associated with the leading causes of preventable death including heart disease, stroke, and type 2 diabetes[1]. Obesity is defined as having a body mass index (BMI) of 30 kg/m^2 or greater. More than one third of adults and 17% of youth in the United States fit this definition[2,3]. Weight management has been widely targeted as an intervention in the obesity epidemic[1]. Although eating patterns as a method for weight management has been studied extensively, the role of breakfast, specifically, remains poorly understood.

Breakfast is widely considered to be the most important meal of the day, but many people do not eat breakfast regularly. Data from the 1971-1974 National Health and Nutrition Examination Survey (NHANES) showed that breakfast consumption among adults decreased from 87% in males and 88% in females to 81% in both males and females in NHANES 2007-2010, representing a 6%-7% decrease in the percentage of adults consuming breakfast over the last 40 years[4]. Many cross sectional studies show an association between breakfast consumption and a lower BMI[5]; however, the limited number of prospective and experimental studies on breakfast skipping vs consumption show inconsistent results[5-7]. In addition, little is known about how the amount of energy consumed at breakfast and the composition of breakfast relate to or impact BMI because very few studies on breakfast have examined these variables. Furthermore, methods to determine energy intake and timing of breakfast have varied across studies making it difficult to understand how energy intake and timing contribute to the notion of breakfast.

In 2007, Timlin and Pereira defined breakfast as the first meal of the day, eaten within 2 hours of waking, no later than 10:00 AM, and containing between 20% and 35% of total daily energy needs[8]. A newer definition of breakfast has been proposed by O'Neil et al: the first meal that breaks a period of fasting, generally overnight, and is eaten within 2 to 3 hours of waking[7]. However, the association between these definitions of breakfast and adiposity has not been studied. Another problem is that most studies on breakfast consumption have not taken into account the wide-spread problem of implausible energy intake reporting, the majority of which is under-reporting in comparison to over-reporting. Overall, the lack of a standard breakfast definition along with differences in methodology across studies and failure to account for self-reporting bias likely contribute to the uncertainty regarding the role of breakfast in weight management.

In a previous study conducted in the McCrory Lab, morning eating patterns in relation to BMI and metabolic syndrome were assessed using two 24 hour multiple pass dietary recalls from the national survey data from NHANES 2005-2010[9]. Morning eating patterns were categorized into early morning and late morning eating occasions. The early morning eating occasion was defined as the first intake of the day occurring between 5 a.m. and 8:59 a.m. The late morning eating occasion was defined as the first intake of the day occurring between 9 a.m. and 11:30 a.m. The results of this study showed that individuals who reported their first intake as early morning on both recalls or late morning on both recalls had a lower BMI compared to those who skipped breakfast. However, when the implausible reporters were excluded from the analysis, the above associations were no longer present. However, in that study composition and energy intake during the morning eating occasion were not examined. Therefore, in addition to the timing of morning eating, in the present study we aimed to examine protein and fiber composition and energy in relation to weight class. Although there have been mixed findings in the few studies on the association of breakfast energy and composition with BMI, we expected that moderate energy intakes during morning eating occasions would be associated with a lower weight status, and that relatively lower and higher energy intakes would be associated with higher weight class. In terms of composition, we expected fiber to have the strongest relationship with weight class followed by protein. In order to reduce the impact of self-reporting bias, implausible reporters were taken into account. Since children are still growing, there may be differences in the relationship of breakfast consumption and BMI between children and adults. Therefore, in this study we only included adults.

CHAPTER II

REVIEW OF LITERATURE

Current Problem

Obesity continues to be one of the largest public health concerns in our nation. It is associated with the leading causes of preventable death including heart disease, stroke, type 2 diabetes, and certain types of cancer[10]. Obesity is defined as a body mass index (BMI) of greater than or equal to 30 kg/m^2 and more than one third of U.S. adults fall into this category[2,3].

Role of breakfast skipping on obesity

Weight management has been widely targeted as an intervention in the obesity epidemic. Although the role of eating patterns as a means for weight management has been widely studied, the role of breakfast, specifically, is still poorly understood.

Breakfast is commonly considered to be the most important meal of the day, but many people do not eat breakfast regularly. Data from the 1971-1974 National Health and Nutrition Examination Survey (NHANES) showed that breakfast consumption among adults decreased from 87% in males and 88% in females to 81% in both males and females in NHANES 2007-2010, representing a 6%-7% decrease in the percentage of adults consuming breakfast over the last 40 years[4]. It is largely assumed that skipping breakfast leads to an increase in body weight due to an increase in appetite leading to overeating and, hence a greater total energy intake throughout the day. However, research to support this common assumption is tenuous.

Current Research

Evidence on the role of skipping breakfast in obesity

Many cross sectional studies show an association between breakfast consumption and a lower BMI. Specifically, a review of 58 studies and 88 study groups found that those who skipped breakfast had a greater predicted risk of being overweight or obese compared to those who ate breakfast[5]. However, these associations do not show causation. Limited prospective and experimental studies on the role of breakfast in obesity have been conducted and show inconsistent results[5-7,11]. This is likely due to the lack of consistent methodology across studies, including absence of a standard breakfast definition. Little is known about how the amount of energy consumed at breakfast and the composition of breakfast relate to or impact BMI because very few studies on breakfast have examined these variables. Furthermore, methods to determine energy intake and timing of breakfast have varied across studies making it difficult to understand how these variables contribute to the notion of breakfast. Understanding these components of breakfast, energy intake, composition, and timing, in relation to adiposity may help to clarify the role of breakfast in managing weight.

Scope of lit review

The possible role of energy intake and composition on adiposity has been examined using various study designs including cross-sectional studies, prospective studies, and experimental trials. For composition, although other dietary factors like energy density, glycemic index, carbohydrate intake, and fat intake may be important the focus will be on protein and fiber due to their role in satiety and weight management[12,13].

Published literature will be reviewed in this area through August 2015 with BMI, weight status, or adiposity as outcomes. Due to inevitable metabolic differences, growing children may show varying results in the relationship between breakfast consumption and adiposity compared to adults. Therefore, only results from previous studies in adults will be used in this literature review. Key terms for this review included, “breakfast skipping” “meal timing” “energy intake at breakfast” “breakfast composition” “BMI” breakfast consumption”.

Gaps in Research

Energy Intake at Breakfast

Cross-sectional studies

Cross sectional studies on the association between energy intake at breakfast and BMI or weight status are show in **Table 1**. The 6 studies[14-19] reviewed show mixed findings. Two of the studies[16,19] show inverse associations when males and females were analyzed together, while one study[15] shows a positive association. In the 2 studies in which male and female were analyzed separately, 1 study[14] shows an inverse association for female and a non-significant association for male, and the other[17] shows a non-significant association for female and an inverse association for male. In one other study[18], energy intake at breakfast was lower in overweight and obese subjects compared to that in normal weight subjects, but whether the association was significant or not was not reported. Thus, most of the studies show that a higher energy intake at breakfast is associated with tendency toward leanness. However, these studies used self-reported dietary data, which is known to be subject to reporting bias. Specifically, the tendency of overweight and obese populations to underreport on dietary assessments can provide inaccurate results due to missing dietary information[15,20,21]. This can include foods high in sugar and fat, such as donuts, pastries, muffins, etc, which are most commonly known to be foods that are underreported and consumed at breakfast[22-27]. Most of these studies did not take implausible energy intake reporting into account. In the one study that did account for implausible reporting, results showed no significant association between breakfast energy and weight status in the total sample of the younger group[15]. However, when only the plausible sub-sample was analyzed, there was a positive association between breakfast energy and normal weight status.

While one reason for the inconsistency of results across studies could be due to implausible dietary reporting, another likely reason is the lack of a standard breakfast definition across studies. In most of these studies the participant defines breakfast[14,16-19], whereas, in one study breakfast was defined as the largest eating occasion before 11 am[15]. The subjective method of the participant defining breakfast leads to inconsistencies of this definition across studies and can generate unreliable results. Furthermore, energy intake at breakfast is expressed in different ways across studies. Three studies uses the percent of total energy intake consumed at breakfast[14-16] while one study uses amount of calories consumed at breakfast[18]. This variance makes it difficult to form a clear conclusion of the results.

In summary, among cross-sectional studies which examined the association between energy intake at breakfast and adiposity, failure to account for self-reporting bias, the lack of a standard breakfast definition, and differences across studies in how energy intake at breakfast is expressed likely contribute to the uncertainty of the role of energy intake at breakfast on weight management.

Table 1: Association of energy intake at breakfast with adiposity in cross-sectional studies in adults

First author, year	Study population	Breakfast definition	Breakfast assessment method	Breakfast energy (kcal/d or %TEI), mean±SEM	Association of breakfast energy with BMI or weight status
Song, 2005 ([14])	N=3,237 MF (655 RTEC consumers; 2,537 non-RTEC consumers) Aged ≥19 y NHANES 1999-2000	Participant-defined	One multiple pass 24h DR	All BF consumers: 416±8 or 18.6 RTEC consumers: 212±8 or 9.9	M: NS [ab] F: -; (OR 0.70 lower for RTEC vs non-RTEC consumption) [ab]
Howarth, 2007 ([15])	N=2,685 MF (1,792 Y; 893 O) Aged 20-59 y (Y); 60-90 y (O) CSFII 1994-1996 plausible reporters	Largest meal before 11:00 AM	Two multiple pass 24h DR	Y: 377±5 or 15.9±0.2 O: 405±9 or 20.4±0.5	MF, Y: + (NW vs OW/OB) NS in total sample [c] MF, O: + (NW vs OW) NS (NW vs OB) NR in total sample
Purslow, 2008 ([16])	N= 6,764 MF 40–75 y EPICN–Norfolk cohort study	Participant-defined	7d estimated food intake record	Q1: 0–11% TEI Q2: 12–14% TEI Q3: 15–17% TEI Q4: 8–21% TEI Q5: 22–50% TEI	MF: - [d]
Kent, 2010 ([17])	N=384 M, 338 F (wave 1) N=244 M, 229 F (wave 2) N=270 M, 62 F (wave 3) Aged ~46.2±0.7 y (M); ~45.4±0.9 y (F) [e]	Participant-defined	Question on relative BF size [f]	NR	M: - (all 3 waves) F: NS (all 3 waves)
Schudziarra, 2011 ([18])	N=100 NW, 280 OW+OB (all MF) Aged 42 y (NW), 45 y (OW+OB)	Participant-defined	14 d (NW) and 10 d (OW+OB) estimated food intake record	NW: 404±19 OW+OB: 364±13	NR

O'Neil, 2014 ([19])	N=18,988 MF Aged >19 y NHANES 2001-2008	Participant-defined	One multiple pass 24h DR	1) Grain/FJ: 487±7 [g] 2) Skippers: 0 3) Grain: 391±9 4) PSRTEC/LFM: 436±8 5) Eggs/Grain/MPF: 515±8 6) RTEC/LFM/WF/FJ: 362±9 7) Coffee/C&S/Sweets: 159±13 8) Cooked Cereal: 429±10 9) MPF/Grain/Eggs: 596±17 10) LFM/WF: 308±15 11) Coffees/Teas: 73±11 12) WF: 173±8	MF: -; OR lower (0.63 to 0.82) in those consuming 1) Grain/FJ; 4) PSRTEC/LFM; 6) RTEC/LFM/WF/FJ; and 8) Cooked Cereal vs 2) Skippers [b]

Abbreviations: BF, breakfast; C&S, coffee and sweets; DR, dietary recall; EI/TEI, ratio of energy intake divided by total energy intake; F, female; FJ, fruit juice; LFM, lower fat milk; M, male; MPF, meat poultry fish; N, sample size; NR, not reported; NS, not significant; NW, normal weight; O, older; OB, obese; OR, odds ratio; OW, overweight; PSRTEC, Presweetened ready to eat cereals; RTEC, ready to eat cereals; SEM, standard error of the mean; TEI, total energy intake; WF, whole fruit; Y, younger.

[a] Model not controlled for exercise; [b] Independent variable was type of breakfast consumed, not energy; [c] See McCrory et al 2011 ([20]); [d] No evidence for a statistically significant interaction with sex; [e] mean±SEM; [f] Large, moderate or small breakfast compared to a standard breakfast consisting of "a bowl of cereal, 1 serving of fruit or juice, 1 cup of milk, and 1 slice of toast with juice" where standard equates with moderate size; skipping breakfast was counted as a small breakfast. [g] Least squared mean ± standard error

Prospective studies

Only one prospective study was reviewed that fit the parameters of our literature search. This study shows an inverse association of energy intake at breakfast and weight change[16]. Percent of total energy intake reported at breakfast using self-reported estimated food intake records were calculated into quintiles. Much like dietary recalls, estimated food intake records are also subject to reporting bias and this study did not take that into account. Furthermore, participants determined their own definition of breakfast and as stated above, this leads to subjectivity that has the potential to generate varying results.

Experimental studies

Experimental studies showing the effect of morning energy intake on adiposity are shown in **Table 2**[28-30]. Two of the studies are crossover designs[28,30] while the third study is a parallel design[29]. The duration of the trials lasted from 2 weeks to 15 weeks. Two studies show a higher energy intake at breakfast resulted in greater weight loss [28,30] while the other study does not show a significant effect[29]. These different findings can be attributed to the same inconsistencies as seen in the cross-sectional and prospective studies on energy intake at breakfast and BMI or weight status.

Timing across all of these studies were similar, but the results were not consistent indicating other methodological issues. Two of the three trials use percent of total energy intake consumed at breakfast[28,29] and the other study uses amount of calories consumed[29,30] to measure energy intake. Additionally, in one of the studies, a 3-day food record was to be completed by each participant for each week of the experiment[30].

Participants were also seen by dietitians twice a week in order to monitor compliance of the experimental diets. Those participants who had a 10% or greater non-compliance rate for three or more days a week were withdrawn from the final analysis. However, there is still a degree of reporting bias even if participants had less than a 10% non-compliance rate, which could affect the outcome of the experimental analysis. The other two experimental trials were conducted in a controlled environment alleviating the potential for implausible energy intake reporting[28,29]. Although two of the three studies show the same effect on adiposity, the presence of reporting bias and differences in methodological approaches in defining breakfast and expressing energy intake make it difficult to understand the role of energy intake at breakfast and weight changes.

Table 2: Effect of energy intake at breakfast on change in adiposity in randomized controlled trials in adults

First author, year	Design	Duration	Study population	Definitions	Treatment	Effect of morning energy intake on change in adiposity
Keim, 1997 ([28])	C	15 wk	10 F Aged 23–39	BF: 8:00 AM–8:30 AM L: 11:30AM–12:00 PM D: 4:30PM–5:00 PM ES: 8:00PM–8:30 PM Lived in metabolic suite 24/7 for duration of experiment	Period 1 Group A: 70% TEI in AM Group B: 70% TEI in PM Period 2 Group A: 70% TEI in PM Group B: 70% TEI in AM	↑ Wt loss and FFM in AM vs PM
Martin, 2000 ([29])	C	2 wk	10 M Aged 28±2 yr BMI 22±2 kg/m^2	BF 7:00AM-9:00 AM Controlled environment	LE, moderate-fat BF (100 kcal, < 10% TEI, 34.4 % energy from fat) HE, low-fat BF (700 kcal, > 25% TEI, 24.6 % energy from fat)	NS
Jakubowicz, 2013 ([30])	P	12 wk	93 OW/OB F Aged 30-57 yrs BMI 32.4 ± 1.8 kg/m2	BF: 6:00AM-9:00 AM L: 12:00PM-3:00 PM D: 6:00PM-9:00 PM 3d record weekly and two dietitian visits per week, noncompliance withdrawn	Two isocaloric groups: Large BF/Small D: 700 kcal breakfast (% energy from Pro/CHO/F = 29/45/26), 500 kcal L, 200 kcal D (65/10/25) Large D/Small BF: 200 kcal BF (65/10/25), 500 kcal L, 700 kcal D (29/45/26)	↑w/ large BF/Small D vs. Large D/Small BF

Abbreviations: BF, breakfast; C, crossover; D, dinner; EI, energy intake; ES, evening snack; FFM, fat-free mass; F, female; HE, high-energy; LF, low-energy; L, lunch; M, male; NS, not significant; OB, obese; OW, overweight; P, parallel; Pro/CHO/F, protein/carbohydrate/fat; TEI, total energy intake

Composition

Protein at breakfast

Dietary protein is a satiating nutrient that reduces hunger and increases feelings of fullness[31,32]. There is evidence to suggest that protein's influence on satiety is due to its' effect on appetite, appetite hormones, and energy intake. The effect of protein, specifically at breakfast, influences satiety by means of our hunger hormones; particularly when consuming higher than normal amounts of protein compared to skipping breakfast[33,34]. Studies support the role of high protein on the inhibition of ghrelin, the appetite-stimulating hormone while increasing peptide YY (PYY) and glucagon-like peptide 1 (GLP-1), which are appetite-suppressing hormones[33,35]. Therefore, consuming a breakfast high in protein may be a dietary strategy to increase satiety.

Although protein intake at breakfast encourages an increased feeling of fullness, there are very few experimental trials to support that this, in turn, reduces subsequent energy intake throughout the day[36]. However, some evidence suggests that a high protein diet may positively regulate ad libitum caloric ingestion[37]. Additionally, during energy restriction, such as when undergoing a weight loss regimen requiring a daily energy intake deficit, a high protein breakfast has been shown to increase initial and sustained satiety[12,32] compared to skipping breakfast[38]. This mechanism has been widely studied and accumulating evidence shows that a breakfast rich in protein may be beneficial for weight loss. However, the effects of protein on long term weight loss and management will likely also depend on composition of carbohydrate, fat[36], and energy density.

The association of protein intake at breakfast with BMI or weight status in adults has not been examined using cross-sectional or prospective studies, but experimental studies have been conducted showing the effects of breakfast protein on changes in adiposity.

Experimental studies

The effect of breakfast protein on changes in body weight/adiposity are shown in **Table 3**[34,35,38]. These studies used a parallel study design and the trials range from 4 weeks to 32 weeks. Even though all three studies show a positive effect of breakfast composition on changes in adiposity[34,35,38], the type of composition contributing to this effect varies. One of these studies found that a high carbohydrate, high protein breakfast has a positive effect on change in adiposity compared to a low carbohydrate breakfast under controlled caloric conditions[35]. Another of these studies focused on analyzing the effects of consuming a high protein, high fiber breakfast and a low protein, low fiber breakfast while controlling for carbohydrate and fat content of the breakfast meal. This study shows that regardless of macronutrient composition of the breakfast meal, skipping breakfast leads to more weight loss compared to eating the breakfast that was provided in the study[38]. The remaining study shows a positive effect on the prevention of gaining fat mass when consuming a high protein breakfast compared to skipping breakfast. However, when comparing the two breakfast meals no significant effect was seen[34].

Only one of the three studies reviewed provide a controlled setting for the experimental trial[38], whereas the other two studies provided free-living participants with instruction on what to consume for breakfast[34,35]. This required the free-living participants to keep 3-day food records[34,35]. As we now know, these methods of assessing dietary intake are subject to reporting bias, potentially leading to inaccurate results. In addition, while one study allows the study participants to define breakfast[35], two studies define breakfast by time and even these definitions are different between the studies[34,38]. These limitations along with the few number of experimental trials make it challenging to conclude the effect of breakfast protein on weight management.

Table 3: Effects of breakfast protein on weight loss in RCTs

First Author, year	Design	Duration	Study Population	Breakfast Definitions	Treatment and Control	Effect of breakfast protein on weight loss
Jakubowicz, 2012 ([35])	P	Diet Intervention: 16 W F/U period: 17-32 W	193 MF obese 40-54yrs	Participant-defined	<u>Treatment</u> Two iso-caloric (600 kcals) BF 1) LC BF (3.3% CH, 40% Pro, 48% Fat) vs 2) HC and Pro BF diet (40% CH, 30% Pro, 30% Fat)	HC and Pro > LC
Geleibter, 2014 ([38])	P	4 W	36 MF Aged 18-65 y BMI > 25 kg/m^2	8:30AM	<u>Treatment</u> 1) Oat porridge (351 kcals, 69% CH, 15% Pro, 17% Fat, 8g fiber) 2) Frosted cornflakes (352 kcals, 75% CH, 8% Pro, 14.5% Fat, 0g fiber) <u>Control</u> BS (11 kcals, 1g CH, 0g Pro, 0.5g Fat, 0g fiber)	BS > HP, LP NS (BF1 vs BF2)
Leidy, 2015 ([34])	P	12 W	54 MF Aged 19 ± 1 y (mean ± SEM) BMI: 29.7 ± 4.6 $kg\ m^{-2}$) (mean ± SEM)	6:00AM-9:45AM	<u>Treatment</u> 1) NP (15% Pro, 350 kcals) 2) HP (40% Pro, 350 kcals) <u>Control</u> BS	HP > BS[a] NS: (NP vs HP)

Abbreviations: AS, afternoon snack; BF, breakfast; BS, breakfast skipping; C, crossover; CH, carbohydrate; D, dinner; EB, energy balance; ER, energy restriction; F, female; FM, fat mass; F/U, follow up; G1, group 1; G2, group 2; HC, high carbohydrate; HF, high fiber; HP, high protein; HP-B, high protein breakfast; HP-D, high protein dinner; HP-E, high protein equally divided among all meals; HP-L, high protein lunch; LC, low carbohydrate; L, lunch; M, male; MS, morning snack; NF, normal fiber; NP, normal protein; NR, not reported; OB, obese; OW, overweight; P; parallel; SEM, standard error of mean; W, weeks;

[a] outcome was weight maintenance

Fiber at breakfast

Similar to protein, fiber has been shown to influence satiety through its effect on appetite, appetite hormones and energy intake[13,39,40]. A systematic review on the effects of dietary fiber showed strengthened positive acute effects on appetite depending on the type of fiber consumed. Long-term fiber supplementation may also have an affect on appetite by means of our appetite hormones. Although studies on the effect of fiber on these hormones are limited, there is some evidence to suggest that fiber induces a decrease in our appetite-stimulating hormone, ghrelin. Some studies also indicate an increase in the appetite-suppressing hormones, PYY and GLP-1, depending on the type of fiber consumed[39,41]. Additionally, fiber has also shown a positive acute and long-term effect on reducing energy intake under ad libitum conditions[13]. These factors combined may contribute to the decrease in body weight seen in more than half of the studies analyzing the effects of fiber on weight management[13].

As recently reviewed by Leidy, et al[11] only one experimental study to date has been conducted showing that a high fiber breakfast decreases adiposity in overweight adults. Although the effects of fiber during the breakfast meal, specifically, have not been extensively studied, it is reasonable to attribute the consumption of fiber at breakfast as a means to positively influence weight management.

Protein and fiber are both nutrients known for their influence on satiety, which can potentially contribute to the long-term effects of weight management. Both nutrients have been seen to increase postprandial satiety and decrease successive hunger potentially leading to a decrease in total daily energy intake. Therefore, it has been suggested that eating a breakfast higher in protein and fiber combined may provide an even greater influence on weight management[11].

Cross-sectional studies

Cross-sectional studies on breakfast fiber are reviewed in **Table 4**[14,15] and show varying results. In the two studies analyzing males and females separately, one study shows an inverse association in females when breakfast is high in fiber density. No significant association was seen in males[14]. The other study does not show a significant association in the relationship of fiber density with BMI[15].

These cross-sectional studies use self-reported dietary data. As discussed previously, this method of dietary collection generates reporting bias. Unless implausible energy intake reporting is accounted for, results may not be accurate. Although one of these studies report results on plausible reporters[15], the other study does not take implausible reporting into account[14]. Furthermore, in one of the studies breakfast is defined by the participant[14] leading to variations in the "breakfast" terminology. There is also not enough information reported in the methodology of the breakfast composition. In one of the studies[14], some of the protein composition is not reported making it unclear how this affected the results. Additionally, other nutrients were included in the methods of both studies that were not controlled for during the study making it difficult to understand the role of fiber only at breakfast.

Similar to the limitations seen previously, reporting bias and lack of a standard breakfast definition, along with gaps in reported methodology inhibits a clear association between breakfast composition and weight status.

Table 4: Association of breakfast fiber with BMI or weight status in cross-sectional studies in adults

First author, year	Study Population	Breakfast Definition	Breakfast Assessment Method	Breakfast composition	Association of breakfast fiber with BMI or weight status
Song 2005 ([14])	N=3,237 MF (655 RTEC consumers; 2,537 non-RTEC consumers) Aged ≥19 y NHANES 1999-2000	Participant-defined	One multiple pass 24h DR	All BF consumers: FD: 1.5g/1000kcal PRO: NR Fat [a]: 27% ED [b]: high RTEC consumers: FD: 2.2g/1000kcal PRO: NR Fat [a]: 8% ED [b]: low	F: - (RTEC consumers vs all BF consumers Men: NS
Howarth, 2007 ([15])	N=893 MF Aged 20-90yrs CSFII 1994-1996 Plausible reporters	Largest meal before 11:00a	Two multiple pass 24h DR	FD (g/kcal) Y: 0.003±0.0004 O: 0.011±0.0004 PRO: NR Fat (% energy): Y: 25.8±0.4 O: 24.0±0.7 ED (kcal/g) Y: .086±0.02 O: 0.74±0.02	NS

Abbreviations: BF, breakfast; BMI, body mass index; C&S, coffee and sweets; DR, dietary record; ED, energy density; F, female; FD, fiber density; FJ, fruit juice; LFM, lower fat milk; M, male; MPF, meat poultry fish; N, sample size; NR, not reported; NS, not significant; O, old; OR, odds ratio; PSRTEC, Presweetened ready to eat cereals; PRO, protein; RTEC, ready to eat cereal; SEM, standard error of the mean; WF, whole fruit; Y, young

[a] calculated as a percent of total breakfast energy reported [b] interpreted based on macronutrient composition reported

The association of fiber intake at breakfast with BMI or weight status in adults has not been examined using prospective studies, nor have experimental studies been conducted showing the effects of breakfast fiber on changes in adiposity.

Timing

As reviewed in a previous study there is accumulating evidence to support that eating earlier compared to eating later in the day may be favorable for weight loss[42]. However, the limited number of prospective and experimental studies on the effects of breakfast timing on weight loss shows mixed results. This is likely due to the inconsistent methodology used to define breakfast, which are clearly shown in the studies presented in Tables 1-4. Breakfast is defined using different times across studies, is self-reported potentially creating a large variability in what is considered to be breakfast among the participants, or a breakfast definition is not reported. Although two breakfast definitions have been proposed[7,8], they have not been tested for their effect on weight changes. Therefore, there is little to no evidence on the effects of breakfast timing on weight change making it difficult to understand how breakfast timing contributes to the relationship of breakfast consumption on weight management.

Summary

The role of breakfast on obesity is still poorly understood due to several limitations across studies in this area. Studies examining the components of the breakfast meal are inconclusive. For example, the expression of energy intake at breakfast is not consistent across studies. In terms of breakfast composition, only a few studies have been conducted which fail to account for other nutrient compositions that can have a confounding effect on weight status. Furthermore, timing of breakfast has varied across studies due to subjective methodology, various timing used to define breakfast, or breakfast timing not being reported. Most studies using dietary recalls fail to account for energy intake reporting bias causing unreliable results if participants are underreporting nutrients that are energy dense and can confound overall results.

The limited number of experimental studies on the effects of breakfast on weight management are also inconclusive. There are wide differences in research methodology in terms of study design and these studies are not long term. The methods to determine energy intake and timing vary across studies making in difficult to understand how these variables impact the notion of breakfast and, in turn, weight management.

Purpose

The goal of this study was to examine the relationship of energy intake, composition, and timing with adiposity during the morning eating occasion in the NHANES 2005-2010 adult participants. Since there is no standard definition of breakfast, we indicated the participant's first reported intake as 'morning eating occasion' rather than breakfast. In order to reduce impact of self-reporting bias, implausible reporters were taken into account. We hypothesized that moderate energy intakes during morning eating occasions (early morning and late morning) would be associated with lower weight status, and that relatively lower and higher energy intakes would be associated with higher weight status. In terms of composition, we hypothesized that protein consumption during the morning eating occasions and fiber consumption during the morning eating occasions would be associated with a lower weight status.

CHAPTER III

METHODS

This was a cross-sectional study involving secondary analysis of data collected as part of the Continuous National Health and Nutrition Examination Survey (NHANES). The analysis expands on a previous study that was conducted in the McCrory Lab by masters student Joy Lee, who examined associations of the timing of morning eating occasions with BMI and metabolic syndrome[9]. This study extends the previous analysis to include composition (fiber and protein) and energy consumed in conjunction with both early and late morning eating occasions for the outcome of weight class only.

Data Procurement

Data from NHANES 2005-2010 were used for this study. NHANES was developed to measure the health and nutritional status of adults and children in the United States through interviews, physical examinations, and laboratory tests. The National Center for Health Statistics of the Centers for Disease Control and Prevention (CDC) designed and implemented the 1999-2010 NHANES. A comprehensive description of the survey methods and analytic guidelines are provided on the CDC website[43]. NHANES uses a complex, multistage sample design rather than a simple random sample to represent the United States (U.S.) population of all ages. NHANES oversamples certain populations in order to provide reliable statistics. These include persons aged 70 years and older, African Americans, and Hispanics. Using trained interviewers and interpreters, standardized questionnaires, interviews, and physical exams were administered to collect data on demographics, diet, medical history, and lifestyle behaviors. Interviews and exams were conducted either at the participant's home or at the mobile exam center (MEC). Two multiple pass 24-hour dietary recalls were administered to obtain dietary intake, the first in-person and the second by telephone.

Variable Selection

Non-pregnant, non-lactating participants aged 20-65 years old who did not perform shift work and who completed two multiple pass 24h dietary recalls were used in the analysis. Data from both 24h recalls were used. For energy, protein and fiber intake, the 2 day mean were used for all subsequent calculations. The independent variable of interest was weight status. The primary independent variables of interest were overweight and obesity. Covariates included race/ethnicity, age, gender, poverty-income ratio (PIR), smoking status, alcohol consumption, physical activity, weight class, self-reported chronic disease, eating frequency, 2 day morning eating pattern, BMI, energy intake reporting plausibility, and when protein and fiber intakes were the independent variables, energy intake during the early morning or late morning time periods and protein or fiber intake the remainder of the day, respectively. Individuals with missing data for any of the variables were excluded.

Dietary Intake and Morning Eating

<u>Timing</u>. The timing of morning eating occasions were defined following methodology used by Lee et al (unpublished) based on the time of first intake reported. Therefore, each of the two 24h recalls were divided into four time periods: time period 1

defined as the first intake of the day occurring between 12:00 a.m. and 4:59 a.m., time period 2 defined as the first intake occurring between 5:00 a.m. and 8:59 a.m., time period 3 defined as the first intake occurring between 9:00 a.m. and 11:30 a.m., and time period 4 defined as the first intake occurring after 11:30 a.m. Time period 2 was designated as "early morning intake" and time period 3 was designated as "late morning intake". Modified quartiles for the late morning period using the quartile cutoffs for the early morning time period was also calculated.

Energy Intake. Reported energy intake (rEI) was calculated for the whole day and for each time period. For early morning and late morning intake, energy was divided into 5 categories. The categories for energy intake included no intake (0 kcals) and, for energy intakes $\geq$ 0.1 kcal, quartiles.

Composition. The protein and fiber variables were used from data available on the dietary recalls. Protein (g) and fiber (g) were calculated for the whole day and for each time period. For early morning and late morning intake, protein and fiber were divided into 5 categories. The categories for protein and fiber included no intake (0 grams) and, for protein or fiber intakes $\geq$ 0.01 g, quartiles were created.

Plausibility of Energy Intake

To determine energy intake reporting plausibility, rEI as a percentage of estimated energy requirements (EER) was calculated. EER for normal weight, overweight, and obese participants were determined using the prediction equations developed by the Institute of Medicine (IOM 2005). The EER equations predict total energy expenditure (TEE) and were developed from a data set of individuals where TEE was measured using the gold standard doubly labeled water method. These equations use height, weight, age, sex, and physical activity level to determine energy needs of an individual. Since the EER equations are intended for maintenance of long-term good health, specific equations for normal weight individuals and overweight and obese individuals were used[1]. The physical activity coefficient in each equation (PA) was taken from a table of values specific to each equation[44].

Outcomes

Participants were categorized as normal weight (BMI 18.5– 24.9 kg/m^2), overweight (BMI 25 -29.9 kg/m^2), or obese (BMI ≥30kg/m^2).

Covariates

Covariates of interest included race/ethnicity, age, gender, poverty-income ratio (PIR), smoking status, alcohol consumption, physical activity, self reported chronic disease, daily eating frequency, the two day morning eating pattern, energy intake before and after morning eating, energy intake reporting plausibility. Race/ethnicity was coded as non- Hispanic Black, non-Hispanic white, Mexican American, other Hispanic, or other race, which includes multi-racial. Gender was coded as male (0) or female (1). The PIR was categorized as ≤ 185% of the poverty line, 185%-299% of the poverty line, and ≥ 300% of the poverty line. Smoking was categorized as ‘yes’ or ‘no’ based on current smoking status. Alcohol consumption in the past year was assessed by NHANES and will be categorized using The Dietary Guidelines for Americans. Moderate consumption of alcohol will equate to ≤ 1 alcoholic beverage per day for women and ≤ 2 alcoholic beverages per day for men. Anything above one alcoholic beverage for women and two alcoholic beverages for men will be categorized as high consumption of alcohol. We chose the NHANES question on physical activity that asked participants if they had engaged in moderate or vigorous activity in the past 30 days to represent the physical activity confounder because NHANES changed their methodology for this question over the years. This question was the only one that worked across all three waves used for our analysis. The physical activity variable was categorized as ‘yes’ or ‘no’ in response to this question. Chronic disease was determined using a combination of multiple questions asked in NHANES. Diseases that were considered included congestive heart failure, coronary heart disease, previous heart attack or stroke, emphysema, thyroid problem, liver condition, cancer, diabetes or kidney disease. Participants were categorized as “1” if they indicated ‘yes’ to questions regarding each of these diseases. Otherwise, they were categorized as “0” for ‘no’. Daily eating frequency was defined as the number of self-reported eating occasions that were > 50 kcals. The two-day morning eating pattern variable was based on the six morning eating patterns previously created. This was used to account for the time of morning eating across both 24h dietary recalls. These patterns were categorized as: “1” early intake on both days; “2” early intake on one day, late intake on the other; “3” early intake one day, no intake the other; “4” late intake both days; “5” late intake one day, no intake the other; and “6” no morning intake on either day. Energy intake before and after morning eating consisted of calories consumed in time period one, between 12:00 a.m. and 4:59 a.m., and in time period four, after 11:30 a.m.

Statistical Methods

Data were analyzed using IBM SPSS Statistics version 21. Each variable was examined to determine distribution and checked for outliers with the aid of scatter plots and graphs. For variables that were not normally distributed, categorical variables were created as described above. These variables included early morning energy intake, late morning energy intake, late morning using early morning energy intake cutoffs, early morning protein and fiber intake, late morning protein and fiber intake, and weight class. Descriptive statistics (median and the interquartile range) were computed for all variables. Multinomial logistic regression analysis was performed to determine associations of morning energy intake, protein, and fiber categories with risk for overweight (OW) and obesity (OB) for both the early morning and late morning time periods. For the energy intake categories, Model 1 was controlled for race/ethnicity, age, gender, poverty-income ratio (PIR), smoking status, alcohol consumption, physical activity, self reported chronic disease, daily eating frequency, and the two day morning eating pattern. Model 2 was controlled for all of the covariates in Model 1 plus energy intake before and after morning eating. Model 3 was controlled for all of the covariates in Model 2 plus energy intake reporting plausibility. For the protein and fiber categories, Models 1, 2, and 3 controlled for the same covariates as the energy intake categories except that in this case, protein or fiber intake the rest of the day replaced energy intake the rest of the day in Models 2 and 3. Models 1, 2, and 3 for the protein and fiber categories also controlled for reported energy intake during the early or late morning eating occasions, respectively. A p-value of <0.05 was considered statistically significant.

CHAPTER IV

RESULTS

Demographic and lifestyle characteristics are shown in **Table 5.** About two-thirds of the study population was male and the median age was 39 years. Non-Hispanic whites made up the majority. Most participants reported being physically active and did not report having a chronic disease. A majority of the population was classified as overweight or obese.

Table 5: Demographic and lifestyle characteristics of the study population

Variable		**Sample (n)**	**Percent**
Age (yrs)	20-29	1031	22.7
	30-39	1289	28.4
	40-49	1162	25.6
	≥ 50	1060	23.3
Gender	Male	2906	64.0
	Female	1636	36.0
Race	Mexican American	980	21.6
	Other Hispanic	402	8.9
	Non Hispanic- White	2106	46.4
	Non Hispanic- Black	847	18.6
	Other (including multi-racial)	207	4.6
Education	Less than 9th grade	413	9.1
	9-11th grade [a]	581	12.8
	High school grad/GED	1003	22.1
	Some college/Associate's degree	1338	29.5
	College grad and above	1204	26.5
	Don't know	3	0.1
Family income to poverty ratio [b]	0-1.84	1435	31.6
	1.85-2.99	780	17.2
	3.00-8.99	2062	45.4
	Don't know	265	5.8
Current smoker	Yes	932	20.5
	No	824	18.1
	Don't know	2786	61.3
Alcohol	Yes	1917	42.2
	No	1422	31.3
	Don't know	1199	26.4
Physical activity	Yes	3372	74.2
	No	1170	25.8

Chronic disease [c]	Yes No Don't know	943 3540 59	20.8 77.9 1.3
Weight status	Normal weight Overweight Obese	1301 1648 1593	28.6 36.3 35.1

[a] 9-11th Grade (Includes 12th grade with no diploma)

[b] 0.00–0.99 indicates below poverty level; ≥1.00 indicates at or above poverty level

Energy Intake

Table 6 reviews the median reported energy intake, protein, and fiber for the whole day and for the morning eating occasions. A median of four eating occasions was reported each day (95% CI: 2.5, 65). Median reported energy intake was reported to be 15% lower than the calculated estimated energy requirements for the whole day. Reported protein intake for the whole day was shown to be greater than the average 56g per day for men and 46g per day for women. Reported fiber intake for the whole day is significantly less than the recommendations set by the Institute of Medicine[45]. The late morning eating occasion had greater reported intake of energy, protein, and fiber compared to the early morning eating occasion. Quartile 4 in all independent variables had a very wide 95% CIs due to a select few participants reporting very large intakes for each respective variable.

Table 7 summarizes the associations of energy intake during the morning eating occasions with BMI. In the early morning analysis, Model 1 showed that, compared to no morning intake there was a lower risk for OB only in Q2. No other relationships were seen in any of the other quartiles. Similar results were seen in Model 2 where a lower risk for OB in Q2 was present. However, after controlling for energy intake reporting plausibility in Model 3 the relationship between energy intake in Q2 and a lower risk for OB disappeared and a higher risk for OW and OB became apparent in Q4.

For the late morning analysis, Models 1 and 2 were similar to each other in that there was no association between morning energy intake category and weight status, but for Model 3 there was a higher risk for OW and OB in Q2, Q3 and Q4. The modified late morning quartile cutoffs showed that a higher risk for OW and OB was still present in

Q2, Q3 and Q4 and the ORs were attenuated compared to when the original late morning cutoffs were used. The differences in risk of OW and OB in Model 2 and Model 3 (after controlling for energy intake reporting plausibility) are depicted in **Figure 1**.

The associations of energy intake during the morning eating occasions with weight status using the highest energy intake category (Q4) as the reference are presented in Appendix Table 1. In both the early morning and late morning analyses, neither Model 1 nor 2 showed an association between the morning energy intake categories and OW or OB. However, Model 3 showed a decreased risk for OW and OB in the no intake category as did Q1-Q3. In the modified late morning quartile cutoffs, Models 1 and 2 show a higher risk for OW in Q2. No other relationships were seen in Q1-Q3. However, in Model 3 there was a decreased risk for OW and OB in the no intake category and Q1-Q3.

Table 6: Median and 95% CIs of reported energy intake, protein, and fiber for the whole day and for the morning only

	Median	95% CI
Energy intake per day		
EER (kcal)	2575	(1995, 3233)
rEI (kcal)	2160	(1105, 3891)
rEI%EER (%)	85	(44, 146)
Protein and fiber intake per day		
Protein (g)	85	(41, 159)
Fiber (g)	15	(6, 34)

Morning energy intake categories					
	No intake	**Q1**	**Q2**	**Q3**	**Q4**
Energy, protein, and fiber intake during the morning					
EM					
rEI (kcal)	0	61 (4, 120)	192 (131, 249)	328 (262, 412)	576 (433, 1077)
rEI%EER (%)	0	2 (0.2, 4.7)	8 (5, 9.9)	13 (10,16)	22 (17,42)
Protein (g)	0	1.3 (0.1, 3.1)	5.5 (3.7, 7.5)	10.7 (8.0, 13.9)	20.8 (14.7, 44.6)
Fiber (g)	0	0.7 (0.1, 1.0)	1.5 (1.1, 2.0)	2.8 (2.1, 3.8)	5.9 (4.0, 14.5)
LM					
rEI (kcal)	0	75 (4, 146)	228 (162, 305)	408 (321, 515)	758 (548, 1460)
rEI%EER (%)	0	3 (0.2, 6)	9 (7, 12)	16 (13, 20)	30 (21, 58)
Protein (g)	0	1.5 (0.1, 4.0)	7.5 (4.7, 10.8)	15.3 (11.4, 20.1)	30.8 (21.4, 66.4)
Fiber (g)	0	0.8 (0.1, 1.2)	1.7 (1.3, 2.3)	3.2 (2.4, 4.3)	6.8 (4.6, 15.7)

Abbreviations: EER, estimated energy requirement; EM, early morning; LM, late morning; rEI, reported energy intake; rEI %EER, reported energy intake as a percent of EER; Q, quartile
EM energy intake: no intake n= 1072, Q1 n= 866, Q2 n=866, Q3 n=870, Q4 n= 868
EM energy intake quartile cutoffs: 25th, 50th, and 75th were 125.99, 255.49, and 422.49 kcals, respectively
LM energy intake: no intake, n= 877, Q1 n= 916, Q2 n=916, Q3 n=917, Q4 n=916
LM energy intake quartile cutoffs: 25th, 50th, and 75th were 153.74, 312.99, and 530.49 kcals, respectively
EM protein: no intake n=1197, Q1 n=836, Q2 n=835, Q3 n=838, Q4 n=836
EM protein quartile cutoffs: 25th, 50th, and 75th were 3.397, 7.779, and 14.267 grams, respectively
EM fiber: no intake n=1801, Q1 n=674, Q2 n=691, Q3 n=693, Q4 n=683
EM fiber quartile cutoffs: 25th, 50th, and 75th were 1.099, 2.049, and 3.849 grams, respectively
LM protein: no intake n=1062, Q1 n=870, Q2 n= 870, Q3 n=870, Q4 n=870
LM protein quartile cutoffs: 25th, 50th, and 75th were 4.296, 11.104, and 20.753 grams, respectively
LM fiber: no intake n=1398, Q1 n=761, Q2 n=794, Q3 n=795, Q4 n=794
LM fiber quartile cutoffs: 25th, 50th, and 75th were 1.249, 2.349, and 4.499 grams, respectively

Table 7: Association of energy intake during early morning and late morning eating occasions with BMI with "no intake" as the reference category [a]

	Morning energy intake categories									
	No intake		**Q1**		**Q2**		**Q3**		**Q4**	
	OW	OB	OW	OB	OW	OB	OW	OB	OW	OB
EM										
Model 1 [b]	--		1.05 (0.73, 1.51)	0.74 (0.50, 1.08)	0.91 (0.58, 1.45)	**0.53 (0.33, 0.86)**	0.86 (0.54, 1.37)	0.59 (0.36, 0.95)	0.97 (0.60, 1.57)	0.64 (0.39, 1.06)
Model 2 [c]	--		1.03 (0.71, 1.48)	0.74 (0.50, 1.09)	0.91 (0.57, 1.43)	**0.54 (0.33, 0.86)**	0.85 (0.53, 1.37)	0.59 (0.36, 0.95)	0.99 (0.61, 1.60)	0.64 (0.38, 1.05)
Model 3 [d]	--		1.01 (0.68, 1.49)	0.73 (0.47, 1.13)	1.02 (0.63, 1.66)	0.76 (0.44, 1.31)	1.37 (0.83, 2.26)	1.77 (1.01, 3.11)	**2.84 (1.67, 4.82)**	**6.74 (3.69, 12.30)**
LM										
Model 1	--		1.05 (0.80, 1.37)	0.90 (0.68, 1.18)	1.11 (0.83, 1.48)	0.95 (0.71, 1.28)	0.82 (0.61, 1.10)	1.00 (0.75, 1.35)	0.86 (0.64, 1.17)	1.01 (0.74, 1.37)
Model 2	--		1.01 (0.77, 1.32)	0.91 (0.69, 1.20)	1.05 (0.78, 1.41)	0.97 (0.72, 1.31)	0.77 (0.57, 1.04)	1.02 (0.76, 1.38)	0.82 (0.60, 1.11)	1.03 (0.76, 1.41)
Model 3	--		1.16 (0.86, 1.56)	1.28 (0.91, 1.79)	**1.97 (1.42, 2.73)**	**4.26 (2.91, 6.24)**	**2.67 (1.89, 3.79)**	**17.89 (11.82, 27.07)**	**12.14 (7.87, 18.74)**	**338.81 (199.22, 576.20)**
LM w/ EM cutoffs [e]										
Model 1	--		1.07 (0.81, 1.41)	0.89 (0.67, 1.18)	1.13 (0.84, 1.51)	1.01 (0.74, 1.36)	0.84 (0.62, 1.13)	0.95 (0.70, 1.28)	0.85 (0.64, 1.14)	1.00 (0.75, 1.35)
Model 2	--		1.03 (0.78, 1.36)	0.90 (0.68, 1.19)	1.07 (0.79, 1.44)	1.02 (0.75, 1.39)	0.80 (0.59, 1.08)	0.96 (0.71, 1.31)	0.80 (0.60, 1.08)	1.03 (0.76, 1.38)
Model 3	--		1.15 (0.86, 1.56)	1.17 (0.83, 1.65)	**1.68 (1.21, 2.32)**	**3.06 (2.10, 4.45)**	**2.06 (1.47, 2.89)**	**8.70 (5.85, 12.93)**	**6.79 (4.61, 10.02)**	**102.14 (64.13, 162.68)**

Abbreviations: EM, early morning; LM, late morning; OW, overweight; OB, obese; Q, quartile

EM: no intake n= 1072, Q1 n= 866, Q2 n=866, Q3 n=870, Q4 n= 868

LM: no intake, n= 877, Q1 n= 916, Q2 n=916, Q3 n=917, Q4 n=916

LM w/ EM cutoffs: no intake n= 877, Q1 n= 736, Q2 n= 805, Q3 n= 815, Q4 n=1309

[a] Values are odds ratios with 95% confidence interval from logistic regression analysis. Values in bold indicate a significant difference in comparison to the reference category (--).

[b] Controlled for gender, race, smoking, alcohol, education, physical activity, chronic disease, age, family income to poverty ratio, number of eating occasions per day, and the 2 day morning intake pattern.

[c] Controlled for all of the covariates in Model 1 plus energy intake before and after morning eating

[d] Controlled for all of the covariates in Model 2 plus energy intake reporting plausibility

[e] Uses quartile cutoffs from early morning energy intake

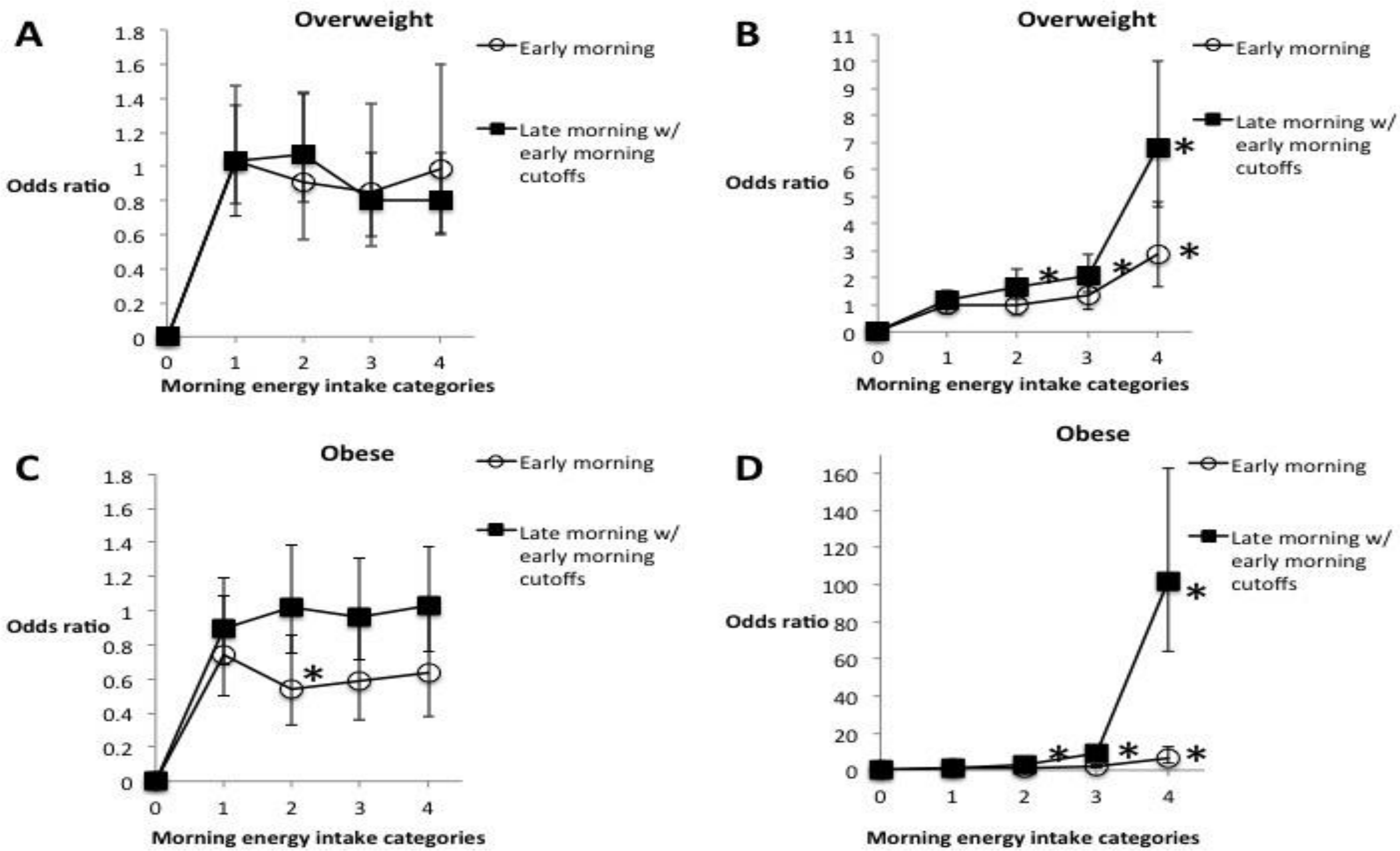

Figure 1. Predicted risk (odds ratio and 95% CI) for overweight without controlling for energy intake reporting plausibility (A) and with controlling for energy intake reporting plausibility (B) and for obesity without controlling for energy intake reporting plausibility (C) and with controlling for energy intake reporting plausibility (D) by morning energy intake category during morning eating occasions. The late morning cutoffs showed significant results in the same energy intake categories for OW and OB as the modified late morning quartile cutoffs. Therefore, only the modified late morning quartile cutoffs are shown in these figures.

Protein

Table 8 summarizes the associations of categories of protein intake during the morning eating occasions with weight status. Compared to no morning intake, there were no significant associations seen between early or late morning protein consumption and weight status in any of the models.

Appendix Table 2 summarizes the associations of categories of protein intake during the morning eating occasions with BMI using the highest amounts of protein consumed as the reference category (Q4). In this analysis, there were no significant associations seen between early morning protein consumption and weight status in any of the models. In the late morning analysis, Models 1 and 2 showed a higher risk for OW in Q3, but in Model 3 in which energy intake reporting plausibility was controlled, these associations were no longer present.

Fiber

Table 9 shows the associations of categories of fiber intake during the morning eating occasions with weight status. For the early morning analysis, Models 1 and 2 did not show an association between the morning fiber intake categories and weight status, but Model 3 showed a lower risk for OB in Q4. For the late morning analysis, Model 1 showed a higher risk for OW in Q2, but no other significant relationships in any of the other quartiles. Similar results were seen in Model 2 where a higher risk for OB in Q2 was present. In Model 3, however, this relationship disappeared and there were no significant associations in any of the other quartiles.

Appendix Table 3 summarizes the associations of categories of fiber intake during the morning eating occasions with weight status using the highest amounts of fiber consumed as the reference category (Q4). In this analysis, there were no significant associations between early morning fiber intake and weight status in Models 1 and 2. In Model 3, however, there was a decreased risk for OB in Q4. Additionally, although there were no significant associations between fiber intake and weight status in Models 1 and 2, Model 3 showed a greater risk OB in Q1 and Q2.

Table 8: Associations of protein intake during early and late morning eating occasions with BMI with "no intake" as the reference category [a]

	Morning intake categories									
	No intake		**Q1**		**Q2**		**Q3**		**Q4**	
	OW	OB	OW	OB	OW	OB	OW	OB	OW	OB
Protein										
EM										
Model 1 [b]	--		1.08 (0.67, 1.75)	1.13 (0.69, 1.85)	0.96 (0.56, 1.65)	1.13 (0.65, 1.97)	1.08 (0.61, 1.91)	1.27 (0.71, 2.27)	1.10 (0.60, 2.02)	1.45 (0.78, 2.68)
Model 2 [c]	--		1.08 (0.67, 1.76)	1.11 (0.68, 1.82)	0.96 (0.56, 1.65)	1.13 (0.65, 1.95)	1.08 (0.61, 1.91)	1.26 (0.70, 2.26)	1.11 (0.61, 2.03)	1.41 (0.76, 2.61)
Model 3 [d]	--		1.01 (0.61, 1.66)	0.98 (0.57, 1.67)	0.77 (0.44, 1.35)	0.74 (0.41, 1.34)	0.83 (0.46, 1.49)	0.74 (0.40, 1.40)	0.87 (0.46, 1.62)	0.85 (0.44, 1.67)
LM										
Model 1	--		1.16 (0.78, 1.73)	1.23 (0.81, 1.86)	1.09 (0.69, 1.72)	1.27 (0.79, 2.04)	1.38 (0.84, 2.26)	1.64 (0.98, 2.74)	1.03 (0.60, 1.75)	1.33 (0.77, 2.30)
Model 2	--		1.16 (0.78, 1.73)	1.24 (0.82, 1.88)	1.09 (0.69, 1.72)	1.28 (0.80, 2.06)	1.37 (0.83, 2.26)	1.67 (1.00, 2.79)	1.02 (0.60, 1.75)	1.35 (0.78, 2.33)
Model 3	--		1.13 (0.75, 1.70)	1.19 (0.76, 1.86)	1.04 (0.65, 1.66)	1.14 (0.68, 1.91)	1.29 (0.77, 2.16)	1.40 (0.80, 2.45)	0.97 (0.56, 1.68)	1.17 (0.64, 2.14)

Abbreviations: EM, early morning; LM, late morning; OW, overweight; OB, obese; Q, quartile
EM protein intake: no intake n=1197, Q1 n=836, Q2 n=835, Q3 n=838, Q4 n=836
LM protein intake: no intake n=1062, Q1 n=870, Q2 n= 870, Q3 n=870, Q4 n=870
[a] Values are odds ratios with 95% confidence interval from multinomial logistic regression analysis. Values in bold are significant in comparison to the reference category (--).
[b] Controlled for gender, race, smoking, alcohol, education, physical activity, chronic disease, age, family income to poverty ratio, early morning energy intake category or late morning energy intake category, number of eating occasions per day, and 2 day morning eating pattern.
[c] Controlled for all of the covariates in Model 1 plus fiber or protein intake before and after morning eating
[d] Controlled for all of the covariates in Model 2 plus energy intake reporting plausibility

Table 9: Associations of fiber intake during early and late morning eating occasions with BMI with "no intake" as the reference category [a]

	Morning intake categories									
	No intake		Q1		Q2		Q3		Q4	
	OW	OB	OW	OB	OW	OB	OW	OB	OW	OB
Fiber										
EM										
Model 1 [b]	--		1.04 (0.77, 1.42)	1.03 (0.75, 1.41)	1.05 (0.75, 1.45)	1.16 (0.84, 1.62)	1.00 (0.71, 1.40)	1.01 (0.72, 1.43)	0.87 (0.60, 1.26)	0.93 (0.64, 1.35)
Model 2 [c]	--		1.04 (0.77, 1.42)	1.03 (0.75, 1.41)	1.05 (0.76, 1.46)	1.17 (0.84, 1.63)	1.01 (0.72, 1.42)	1.02 (0.72, 1.45)	0.90 (0.62, 1.30)	0.96 (0.67, 1.39)
Model 3 [d]	--		0.97 (0.71, 1.33)	0.92 (0.66, 1.28)	0.90 (0.64, 1.26)	0.91 (0.65, 1.29)	0.88 (0.62, 1.24)	0.80 (0.55, 1.15)	0.73 (0.50, 1.07)	**0.66 (0.44, 0.97)**
LM										
Model 1	--		1.10 (0.82, 1.49)	1.36 (1.00, 1.84)	**1.52 (1.11, 2.08)**	1.24 (0.90, 1.73)	1.36 (0.97, 1.90)	1.23 (0.87, 1.73)	1.37 (0.96, 1.98)	0.99 (0.68, 1.45)
Model 2	--		1.10 (0.82, 1.48)	1.36 (1.00, 1.84)	**1.52 (1.10, 2.08)**	1.24 (0.89, 1.73)	1.37 (0.98, 1.92)	1.23 (0.87, 1.75)	1.42 (0.98, 2.04)	1.01 (0.69, 1.48)
Model 3	--		1.05 (0.77, 1.42)	1.26 (0.92, 1.73)	1.34 (0.97, 1.85)	1.00 (0.71, 1.41)	1.17 (0.83, 1.65)	0.93 (0.64, 1.33)	1.17 (0.80, 1.70)	0.71 (0.47, 1.05)

Abbreviations: EM, early morning; LM, late morning; OW, overweight; OB, obese; Q, quartile
EM fiber intake: no intake n=1801, Q1 n= 674, Q2 n= 691, Q3 n= 693, Q4 n= 683
LM fiber intake: no intake n=1398, Q1 n=761, Q2 n=794, Q3 n=795, Q4 n=794
[a] Values are odds ratios with 95% confidence interval from multinomial logistic regression analysis. Values in bold are significant in comparison to the reference category (--).
[b] Controlled for gender, race, smoking, alcohol, education, physical activity, chronic disease, age, family income to poverty ratio, early morning energy intake category or late morning energy intake category, number of eating occasions per day, and 2 day morning eating pattern.
[c] Controlled for all of the covariates in Model 1 plus fiber or protein intake before and after morning eating
[d] Controlled for all of the covariates in Model 2 plus energy intake reporting plausibility

CHAPTER V

DISCUSSION/CONCLUSION

We examined the relationships of energy, protein, and fiber intake during morning eating occasions in addition to timing of morning eating with risk for overweight or obesity using national survey data from NHANES 2005-2010. In the early morning (5-8:59 am), in comparison to those who had no intake (i.e., “skipped”), individuals who consumed 126-256 kcals showed a decreased risk for OB. However, after controlling for energy intake reporting plausibility, this association was no longer present, and instead, there was a 2.8 times greater risk for OW and 6.7 times greater risk for OB when consuming ≥ ~ 423 kcals during this time. Furthermore, during the late morning (9-11:30 am), compared to those who had no intake, ≥ ~154 kcals consumed was associated with a 12 times greater risk for OW and 339 times greater risk for OB. All of these associations were independent of energy intake the rest of the day, eating frequency, and other demographic and lifestyle confounders. The much higher risk for OW and OB in the late morning compared to the early morning eating may, in part, have been due to the higher amounts of energy consumed during the late morning. Concerning fiber intake in the early morning, after controlling for energy intake reporting plausibility, we observed that compared to those who had no fiber intake, individuals who consumed ≥ 3.9 g had a 40% decreased risk for OB, independent of fiber intake the rest of the day and the other confounders noted above. There were no associations of fiber intake in the late morning, or protein intake in either the early or late morning, with OW or OB. Overall, higher energy intake in both the early morning and late morning, and lower fiber intake in the early morning may elevate the risks for OW and OB. Furthermore, breakfast "skipping" in either the early morning or late morning was not associated with an increased risk for excess adiposity. Like the few previous epidemiological studies which have taken into account energy intake reporting plausibility, our analysis also confirms the importance of doing so, since the associations of energy and fiber with OW and OB were not apparent otherwise.

It is commonly believed that breakfast skipping increases the risk for weight gain and many previous cross sectional and longitudinal studies support an inverse association between breakfast skipping and higher adiposity[19,46,47]. Our results were not consistent with these previous findings. Prior to controlling for energy intake reporting plausibility, our findings initially showed only moderate amounts of energy in the early morning eating occasion to have a little over 50% decreased risk for OB compared to those who had no intake. This association is consistent with the findings of several cross-sectional studies that have shown a negative association with energy intake consumed at breakfast and BMI or weight status[14,16,17,19], but those studies did not account for implausible energy intake reporting. After adjusting the statistical model for energy intake reporting plausibility, the association disappeared. Instead, consuming higher amounts of energy in the early or late morning eating occasions showed a positive association with risk for OW and OB. These results are congruent with a cross-sectional study conducted by Howarth, et al showing a positive association between energy intake prior to 11a.m. and OW and OB among the plausible subsample only[15]. Our findings are inconsistent with the results of experimental trials lasting between 12 and 15 weeks in which higher amounts of energy at breakfast resulted in a decrease in adiposity[28,30]. Although one of these studies was in an experimental setting to avoid non-compliance issues, the timing used to define breakfast was very narrow (8-8:30a) and the sample size was very small and gender specific (10 female participants)[28]. The other study required participants to keep a 3-day weekly record of their food intake, which can lead to potential underreporting[30]. Since foods high in sugar and fat are foods to be commonly underreported[25,26,48] this can lead to reporting bias and cause inaccurate overall results related to associations with adiposity.

Regarding breakfast composition, contrary to our hypothesis, protein did not have a significant relationship with weight status in the early or late morning eating occasions. These results conflict with several experimental studies that have shown protein consumption at breakfast to result in greater weight loss compared to those who skip breakfast[34,35,38], regardless of whether the amount of protein consumed is a high amount or a normal amount. Therefore, it is difficult to interpret whether the protein, calories, or both in the breakfast meal contribute to the greater weight loss compared to those who skip breakfast. We observed that fiber, on the other hand, showed a 33% decreased risk for OB when consuming ~ ≥3.9 grams of fiber only after controlling for energy intake reporting plausibility. These findings are consistent with a cross-sectional study conducted by Song et al showing an association between higher fiber intake at breakfast and lower BMI[14]. However, other nutrients were not controlled for making it difficult to interpret if the association was due to differences in fiber between the breakfast groups or to an interaction effect of fiber, fat, and energy density. Literature describes protein and fiber to be nutrients that contribute towards feelings of fullness, and therefore, are potentially involved in eating patterns for weight management[11-13,31,32], but there is very little research on the consumption of these nutrients during the morning meal, specifically, to support this. In general, consuming very high amounts of dietary fiber has been shown to decrease adiposity[49-51]. Our study supports these findings for the morning meal.

It is commonly believed that breakfast skipping increases the risk for weight gain and many previous cross sectional and longitudinal studies support an inverse association between breakfast skipping and higher adiposity or weight gain[19,46,47]. Our results, which were apparent only after controlling for implausible energy intake reporting, were not consistent with these previous findings and were more consistent with the majority of experimental studies lasting longer than 1 day showing no effect of breakfast skipping on body weight[52-56]. One of the biggest challenges in the research on breakfast consumption and weight status is that implausible energy intake reporting is not taken into account in most studies, which can lead to inaccurate or biased results. It has been previously studied that certain foods and nutrients tend to be underreported[27], specifically with breakfast and snacks[20] among overweight and obese individuals[15]. The varying relationships seen in our study after controlling for reporting bias and a previous study looking at only the plausible subsample[15], demonstrate the importance of considering the confounding influence of implausible energy intake reporting in future epidemiological studies on dietary associations and weight status.

A major strength of this study was using an established method to account for implausible energy intake reporting[21]. It was evident with our findings that the relationship differed from the original models that did not account for this. Another strength was categorizing morning eating by time period instead of calling a particular morning eating occasion “breakfast.” Since participants reported eating multiple times per day, the categorized time periods alleviated the potential for subjectively choosing which eating occasion would be considered breakfast as there is no standard definition. In addition, whether someone eats in the early morning or late morning can be confounded by eating frequency, and we did control for eating frequency whereas most previous studies on breakfast in relation to adiposity do not. Finally, we controlled for chronic disease, which can sometimes cause a predisposition to being overweight or obese for reasons that are not associated with eating patterns.

There were also some limitations associated with our study. Due to the epidemiological nature of our study, our findings are strictly observational and no cause and effect can be determined from these associations. It would be expected that individuals with higher BMIs would consume higher amounts of energy in general than normal weight individuals due to higher energy needs. However, we did control for energy intake both before and after morning eating occasions to try to determine whether a unique relationship between energy intake in the morning and weight status existed. In terms of categorizing our independent variables, the time period cutoffs for the early morning and late morning eating occasions were arbitrary and the categories for energy, protein, and fiber were based on the data and not on an absolute standard. We also did not examine other dietary factors that could potentially have an impact on the association of breakfast consumption and weight status, such as energy density, fat intake, whole grain and/or other carbohydrate intake in addition to fiber. Lastly, we did not account for the clustered sample survey design used in NHANES. This design incorporates differential probabilities of selection to ensure samples are representative of the population. Including sample weights would provide data that are representative of the population as a whole and help eliminate biases in estimation due to differing probabilities in selection, certain types of non-response, and adjustment to independent estimates of certain population sizes[57].

In conclusion, our study showed that large amounts of energy in the early and late morning eating occasions have a positive association with risk for OW and OB. In terms of composition, we showed that large amounts of fiber to have a significantly decreased risk for OB in the early morning eating occasion only, but protein did not have an association with risk for OW and OB in the early or late morning eating occasions. These associations were only seen after accounting for reporting bias illustrating that this could be an important step to ensure validity of results. It is difficult to compare this study to other cross-sectional studies due to the variability in methodology including defining morning eating (as breakfast or otherwise) and methods to express energy intake (kcals vs. %TEI) and composition (grams vs %energy). In addition to the variables used in this study future studies should also examine the amount of time between waking and eating to further assess the relationship between morning eating and weight status. Long-term randomized control studies also need to be conducted in order to determine a cause and effect relationship.

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APPENDIX

Table 1: Association of energy intake during early morning and late morning eating occasions with BMI with "Q4" as reference category [a]

	Morning energy intake categories									
	No intake		**Q1**		**Q2**		**Q3**		**Q4**	
	OW	OB	OW	OB	OW	OB	OW	OB	OW	OB
EM										
Model 1 [b]	1.03 (0.64, 1.68)	1.56 (0.95, 2.58)	1.08 (0.79, 1.49)	1.15 (0.95, 1.59)	0.94 (0.72, 1.24)	0.83 (0.63, 1.10)	0.88 (0.69, 1.14)	0.91 (0.71, 1.18)	--	
Model 2 [c]	1.01 (0.62, 1.65)	1.57 (0.95, 2.60)	1.04 (0.76, 1.44)	1.17 (0.84, 1.62)	0.92 (0.70, 1.20)	0.85 (0.64, 1.12)	0.87 (0.68, 1.11)	0.92 (0.71, 1.19	--	
Model 3 [d]	**0.35 (0.21, 0.60)**	**0.15 (0.08, 0.27)**	**0.36 (0.25, 0.51)**	**0.11 (0.07, 0.16)**	**0.36 (0.26, 0.49)**	**0.11 (0.08, 0.16)**	**0.48 (0.37, 0.64)**	**0.26 (0.19, 0.36)**	--	
LM										
Model 1	1.16 (0.86, 1.57)	0.99 (0.73, 1.35)	1.22 (0.94, 1.58)	0.89 (0.68, 1.16)	1.28 (1.00, 1.64)	0.95 (0.73, 1.22)	0.95 (0.74, 1.20)	1.00 (0.78, 1.27)	--	
Model 2	1.23 (0.90, 1.67)	0.97 (0.71, 1.32)	1.23 (0.95, 1.60)	0.88 (0.68, 1.15)	1.29 (1.00, 1.65)	0.94 (0.73, 1.22)	0.94 (0.74, 1.20)	0.99 (0.78, 1.26)	--	
Model 3	**0.08 (0.05, 0.13)**	**0.003 (0.002, 0.01)**	**0.10 (0.07, 0.14)**	**0.004 (0.002, 0.01)**	**0.16 (0.12, 0.23)**	**0.01 (0.01, 0.02)**	**0.22 (0.16, 0.30)**	**0.05 (0.04, 0.08)**	--	
LM w/ EM cutoffs [e]										
Model 1	1.18 (0.88, 1.57)	1.00 (0.74, 1.34)	1.26 (0.97, 1.62)	0.88 (0.68, 1.15)	**1.33 (1.04, 1.68)**	1.00 (0.78, 1.28)	0.99 (0.79, 1.24)	0.94 (0.75, 1.19)	--	
Model 2	1.24 (0.93, 1.67)	0.98 (0.73, 1.31)	1.28 (0.99, 1.65)	0.88 (0.67, 1.14)	**1.33 (1.05, 1.68)**	1.00 (0.78, 1.28)	0.99 (0.79, 1.24)	0.94 (0.75, 1.19)	--	
Model 3	**0.15 (0.10, 0.22)**	**0.01 (0.01, 0.02)**	**0.17 (0.12, 0.24)**	**0.01 (0.01, 0.02)**	**0.25 (0.18, 0.34)**	**0.03 (0.02, 0.04)**	**0.30 (0.23, 0.40)**	**0.09 (0.06, 0.12)**	--	

Abbreviations: EM, early morning; LM, late morning; OW, overweight; OB, obese; Q, quartile
Early morning: no intake n= 1072, Q1 n= 866, Q2 n=866, Q3 n=870, Q4 n= 868
Late morning: no intake, n= 877, Q1 n= 916, Q2 n=916, Q3 n=917, Q4 n=916
Late morning modified cutoffs: no intake n= 877, Q1 n= 736, Q2 n= 805, Q3 n= 815, Q4 n=13

[a] Values are odds ratios with 95% confidence interval from logistic regression analysis. Values in bold indicate a significant difference in comparison to the reference category (--).

[b] Controlled for gender, race, smoking, alcohol, education, physical activity, chronic disease, age, family income to poverty ratio, number of eating occasions per day, and the 2 day morning intake pattern.

[c] Controlled for all of the covariates in Model 1 plus energy intake before and after morning eating
[d] Controlled for all of the covariates in Model 2 plus energy intake reporting plausibility
[e] Uses quartile cutoffs from early morning energy intake

Table 2: Association of protein intake during early and late morning eating occasions with BMI with "Q4" as reference category [a]

	Morning protein and fiber intake categories									
	No intake		**Q1**		**Q2**		**Q3**		**Q4**	
	OW	OB	OW	OB	OW	OB	OW	OB	OW	OB
Protein										
EM										
Model 1 [b]	0.91 (0.50, 1.66)	0.69 (0.37, 1.28)	0.98 (0.66, 1.46)	0.78 (0.52, 1.18)	0.87 (0.63, 1.21)	0.79 (0.56, 1.10)	0.98 (0.73, 1.30)	0.88 (0.65, 1.18)	--	
Model 2 [c]	0.90 (0.49, 1.65)	0.71 (0.38, 1.32)	0.98 (0.66, 1.46)	0.79 (0.53, 1.19)	0.87 (0.63, 1.21)	0.80 (0.57, 1.12)	0.97 (0.73, 1.30)	0.90 (0.66, 1.21)	--	
Model 3 [d]	1.16 (0.62, 2.17)	1.17 (0.60, 2.29)	1.17 (0.77, 1.77)	1.14 (0.73, 1.78)	0.89 (0.63, 1.26)	0.86 (0.60, 1.25)	0.96 (0.71, 1.29)	0.87 (0.63, 1.20)	--	
LM										
Model 1	0.98 (0.57, 1.66)	0.75 (0.44, 1.31)	1.13 (0.76, 1.68)	0.93 (0.62, 1.39)	1.06 (0.76, 1.49)	0.96 (0.68, 1.34)	**1.34 (1.01, 1.79)**	1.23 (0.93, 1.65)	--	
Model 2	0.98 (0.57, 1.67)	0.74 (0.43, 1.29)	1.13 (0.76, 1.68)	0.92 (0.62, 1.39)	1.06 (0.76, 1.49)	0.95 (0.68, 1.34)	**1.34 (1.01, 1.79)**	1.24 (0.93, 1.65)	--	
Model 3	1.03 (0.59, 1.80)	0.85 (0.47, 1.56)	1.16 (0.77, 1.76)	1.01 (0.65, 1.58)	1.07 (0.75, 1.52)	0.97 (0.67, 1.42)	1.34 (0.99, 1.81)	1.19 (0.87, 1.64)	--	

Abbreviations: EM, early morning; LM, late morning; OW, overweight; OB, obese; Q, quartile
Early morning protein intake: no intake n=1197, Q1 n=836, Q2 n=835, Q3 n=838, Q4 n=836
Late morning protein intake: no intake n=1062, Q1 n=870, Q2 n= 870, Q3 n=870, Q4 n=870
[a] Values are odds ratios with 95% confidence interval from multinomial logistic regression analysis. Values in bold are significant in comparison to the reference category (--).
[b] Controlled for gender, race, smoking, alcohol, education, physical activity, chronic disease, age, family income to poverty ratio, early morning energy intake category or late morning energy intake category, number of eating occasions per day, and 2 day morning eating pattern.
[c] Controlled for all of the covariates in Model 1 plus fiber or protein intake before and after morning eating
[d] Controlled for all of the covariates in Model 2 plus energy intake reporting plausibility

Table 3: Association fiber intake during early and late morning eating occasions with BMI with "Q4" as reference category [a]

	Morning protein and fiber intake categories									
	No intake		**Q1**		**Q2**		**Q3**		**Q4**	
	OW	OB	OW	OB	OW	OB	OW	OB	OW	OB
Fiber										
EM										
Model 1 [b]	1.04 (0.77, 1.42)	1.03 (0.75, 1.41)	1.05 (0.75, 1.45)	1.16 (0.84, 1.62)	1.00 (0.71, 1.40)	1.01 (0.72, 1.43)	0.87 (0.60, 1.26)	0.93 (0.64, 1.35)	--	
Model 2 [c]	1.04 (0.77, 1.42)	1.03 (0.75, 1.41)	1.05 (0.76, 1.46)	1.17 (0.84, 1.63)	1.01 (0.72, 1.42)	1.02 (0.72, 1.45)	0.90 (0.62, 1.30)	0.96 (0.67, 1.39)	--	
Model 3 [d]	0.97 (0.71, 1.33)	0.92 (0.66, 1.28)	0.90 (0.64, 1.26)	0.91 (0.65, 1.29)	0.88 (0.62, 1.24)	0.80 (0.55, 1.15)	0.73 (0.50, 1.07)	**0.66 (0.44, 0.97)**	--	
LM										
Model 1	0.73 (0.51, 1.05)	1.01 (0.69, 1.47)	0.80 (0.59, 1.09)	1.37 (1.00, 1.87)	1.10 (0.83, 1.47)	1.25 (0.93, 1.69)	0.99 (0.76, 1.29)	1.23 (0.94, 1.62)	--	
Model 2	0.71 (0.49, 1.02)	0.99 (0.68, 1.44)	0.78 (0.57, 1.06)	1.34 (0.98, 1.84)	1.07 (0.80, 1.43)	1.23 (0.91, 1.65)	0.97 (0.74, 1.26)	1.22 (0.93, 1.60)	--	
Model 3	0.86 (0.59, 1.24)	1.42 (0.95, 2.12)	0.90 (0.65, 1.23)	**1.78 (1.28, 2.49)**	1.15 (0.86, 1.54)	**1.42 (1.04, 1.94)**	1.01 (0.77, 1.32)	1.31 (0.98, 1.76)	--	

Abbreviations: EM, early morning; LM, late morning; OW, overweight; OB, obese; Q, quartile
Early morning: no intake n= 1072, Q1 n= 866, Q2 n=866, Q3 n=870, Q4 n= 868
Late morning: no intake, n= 877, Q1 n= 916, Q2 n=916, Q3 n=917, Q4 n=916
[a] Values are odds ratios with 95% confidence interval from multinomial logistic regression analysis. Values in bold are significant in comparison to the reference category (--).
[b] Controlled for gender, race, smoking, alcohol, education, physical activity, chronic disease, age, family income to poverty ratio, early morning energy intake category or late morning energy intake category, number of eating occasions per day, and 2 day morning eating pattern.
[c] Controlled for all of the covariates in Model 1 plus fiber or protein intake before and after morning eating
[d] Controlled for all of the covariates in Model 2 plus energy intake reporting plausibility