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Breakfast Boost Study: Defining the role of breakfast macronutrient composition on markers of childhood obesity

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Abstract

Background: Childhood obesity is a serious problem in the United States, affecting ~19% of children 2-19 years of age. Breakfast is a key component of a healthy diet and can positively impact children's health. However, there has been a steady decline in breakfast consumption in children over the past 40 years.

Methods: The objective of this study was to determine if breakfast macronutrient composition, protein (PRO)-based breakfast (30 g protein, 31 g carbohydrate, 11.7 g fat) or an isocaloric (360 kcal) carbohydrate (CHO)-based breakfast (13 g protein, 48 g carbohydrate, 11.7 g fat), can influence postprandial appetite and food intake in overweight/obese (OW; n=8) versus normal weight (NW; n=14) children ages 7-17 years old. Male and females participated in this randomized, double-blind study. Participants arrived fasted and received either a PRO or CHO breakfast. Appetite was measured using visual analog scales over 4 hours. Food intake was recorded using weighed food records. Energy expenditure was measured via indirect calorimetry over 4 hours. Data was analyzed using two-factor, repeated measures ANOVA or two-sample independent t-test.

Results: Overall, there was no significant difference in perceived hunger response between breakfasts, however OW tended to be hungrier and less full than NW following the meal. There was a significant effect of diet and weight on perceived fullness. There was a difference in breakfast composition on energy expenditure, with PRO having a higher ($P<0.05$) energy expenditure than CHO. There was no difference in taste between the two breakfasts.

Conclusion: Taken together, these data suggest that body weight and breakfast type influence perceived fullness and postprandial energy expenditure but that neither body weight nor breakfast type influence perceived hunger, strength of the desire to eat or food intake.

Introduction

“In the United States, the percentage of children and adolescents affected by obesity has more than tripled since the 1970s” (Fryar, Carroll & Ogden, 2014). Over the last 15 years, there has been a significant increase in the prevalence of obesity, with the percentage in 2015-2016 rising to 18.5 among youth. With the goals of Healthy People 2020 aimed at achieving a national level of obesity of 14.5% or lower, it is clear that the current prevention and treatment plans are not effective or widespread enough to reduce obesity rates (Nutrition, Physical Activity & Obesity, 2014). The 2016 study by Al-Agha, Al-Ghamdi and Halabi found that “childhood obesity has become a worldwide health hazard (2016). These risks to health include a substantial increased risk for cardiovascular disease (May, Kuklina, & Yoon, 2012; Mueller, Enderle & Bosy-Westphal, 2016), increased physical limitations, attention difficulty, degenerative joint diseases in weight bearing joints and social challenges (Al-Agha, Al-Ghamdi & Halabi, 2016). It is also associated with the onset of mental health conditions such as anxiety, depression, and stress (Al-Agha, Al-Ghamdi & Halabi, 2016). In light of the research findings above, there is a need to develop a comprehensive prevention plan and treatment strategy to combat the prevalence of childhood obesity.

This research seeks to fill this knowledge gap. To narrow the study, I will focus on the difference in energy metabolism, appetite and food intake with macronutrient composition of breakfast. To come to conclusive results, we will have normal weight, overweight and obese participants that will be randomly assigned to one of two breakfast groups: carbohydrate or protein.

Although obesity is linked to several variables, it can be simplified to a balance between energy intake and energy expenditure (Hill, Wyatt & Peters, 2012). This study aimed to evaluate the role of energy intake versus energy expenditure in response to breakfast with the hypothesis that a breakfast with a higher protein content, 30 grams of protein, will increase energy expenditure and decrease energy intake (through changes in appetite) in overweight and obese children compared to the carbohydrate breakfast with 13.1 grams of protein. BMI will be used to determine if a child is overweight or obese based on the classifications (CDC, 2018).

Review of Literature

Body mass index (BMI) is considered to be a direct measure of body fatness. “BMI is calculated by dividing a person’s weight in kilograms by the square of height in meters” (CDC, 2018). The Center for Disease Control (CDC) recommends that BMI be categorized by percentile when measuring the bodies of children and young people aged 2-20 years. This is due to children’s body composition differences as a result of age and sex. BMIs above the 5th and below the 85th percentiles are considered normal weight, at or above the 85th percentile is categorized as overweight, and at or above the 95th percentile is obese (CDC, 2018).

“Nearly one-third of all children and youth in the United States are either overweight or obese” (Dietary Guidelines for Americans, 2015). Obesity, defined as having excess body fat, has more than tripled since the 1970s in the United States (CDC, 2018). The prevalence of childhood obesity was measured to be 18.5% in youth from 2015-2016 (CDC, 2017). Also calculated in 2015-2016 was that nearly 1 in 5 school aged children and young people 6-19 years suffer from obesity in the United States (CDC, 2018). This prevalence is higher than the current objectives of 14.5% obesity in youth, set in Healthy People 2020 (Nutrition, Physical Activity, & Obesity, 2014).

“Children with obesity are at a higher risk of having other chronic health conditions and diseases that influence physical health.” Including things like asthma, sleep apnea, bone problems, joint problems, and type 2 diabetes (CDC, 2018). In a national study it was indicated that, in the United States, overweight and obese children and adolescents have a substantial risk of cardiovascular disease. A higher BMI was also linked to increased physical disability, attention disorders, and social problems, particularly in obese children (Al-Agha, Al, Ghamdi & Halabi, 2016). Higher BMI percentiles are also associated with severe comorbidities, including mental conditions like anxiety and depression as well as other physical conditions like joint diseases to weight bearing joints (Al-Agha, Al-Ghamdi & Halabi, 2016).

Weight loss and gain are associated with changes in energy expenditure (EE), which measures the metabolic activity of the body, and specifically the fat free mass (Mueller, Enderle & Bosy-Westphalia, 2016). Weight loss is due to a negative energy balance and is the result of a new equilibrium of intake and EE (Heymsfield, Nguyen, Peng, Heymsfield et al., 2011). "Measurement of EE in humans is required to assess metabolic needs, fuel utilization, and the relative thermic effect of different food, drink, drug and emotional components" (Levine, 2007).

It has been proven that diets higher in protein and lower in carbohydrate can improve body composition and increased postprandial energy metabolism in adults. Consumption of protein also resulted in greater appetite control and satiety than carbohydrates (Baum, 2015). The meal-induced thermogenesis at 2.5 hours post meal average around two times higher on a high protein, low fat diet when compared to a high carbohydrate, low fat diet (Johnston, Day & Swan, 2002). It has also been determined that high-protein, low glycemic index combination is protective against obesity in a sample of children (Papadaki, Linardakis, Larsen, Van Baak, Lindroos, Pfeiffer & Kafatos, 2010). However, there is limited information about the effects of breakfast macronutrient composition in children. It has been determined that not only the frequency of breakfast consumption, but the composition of breakfast can potentially reduce the rise of development of obesity (Baum, 2015).

Proteins are macromolecules composed of peptide bonded amino acids (Haurowitz & Koshland, 2020). Proteins are essential to bodily function and required for proper structure and function of all body processes (Webb, 1999). Proteins, and amino acids are often called the building blocks of life (Wax, 2019). Recent literature supports that high-protein, reduced fat diets will improve weight loss, insulin sensitivity, and blood lipid profiles. This is due to a rise in postprandial energy expenditure for four to five hours after a meal (Johnston, Day, & Swan, 2002). This rise in energy expenditure is thought to be linked to the lack of storage for dietary protein, causing it to be broken down and used immediately (Baum, 2015). High protein diets are also linked to weight loss because of the thermic response, which is 50-100% higher compared to carbohydrate. This difference is thought to be because of the high energy required to break the bonds unique to proteins (Johnston, Day & Swan, 2002). It is also accepted that high protein meals increase the reports of fullness. When subsequent food intake is used to measure satiety, often there is a decrease in intake of food after protein consumption (Latner & Schwartz, 1999). However, the effect of increasing protein at breakfast on hunger, postprandial energy metabolism (TEF), and food intake in school-aged children is unknown. High protein diets in general have not been studied in children. Results from one randomized study suggest that diets higher in protein with a low glycemic index can be protective against obesity in children aged 5-18 (Papadaki, Linardakis, Larsen, Van Baak, Lindroos, Pfeiffer & Kafatos, 2010).

Carbohydrates are units of sugar and are subdivided based on type and amount of sugar units into simple sugars, starches, and fiber. The primary role of dietary carbohydrate is to provide energy for the body, but the nutritive value of carbohydrate varies between types (Salvin et al, 2014). “High-carbohydrate diets have previously been found to result in self-reports of lower satiety and greater motivation to eat then equicaloric high-protein meals” (Latner & Schwartz, 1999). It is also reported that there is a significant increase in hunger after the meal, and an increase in excitement about eating again. A greater satisfaction was achieved while eating dinner after a high carbohydrate lunch (Latner & Schwartz, 1999). This is because carbohydrate consumption causes a less impactful rise in energy expenditure, which rapidly falls shortly after the meal. This suggests that perhaps recommendations in the U.S Dietary Guidelines should be adjusted to decrease the percentage of carbohydrate consumption, where it is currently recommended to comprise 58% of calories (Johnston, Day & Swan, 2002).

Materials and Methods

Study Design

This study used a randomized, double-blind design to measure food intake, appetite, and energy expenditure in overweight and obese children versus normal weight children consuming either a protein-based or carbohydrate-based breakfast.

Overall Objective

The objective of this study was to determine the impact of macronutrient composition on food intake, appetite and energy expenditure in overweight and obese children.

Aim 1

To describe the food intake, appetite and energy expenditure of overweight and obese children consuming a high protein breakfast.

Aim 2

To describe the food intake, appetite and energy expenditure of overweight and obese children consuming a high carbohydrate breakfast.

Aim 3

To compare the food intake, appetite and energy expenditure in overweight and obese children when consuming carbohydrate vs. protein breakfasts.

Participant Recruitment

Male and female normal weight and overweight/obese children ages 7-17 were recruited to participate in this study (see **Table 1** for participant characteristics). Normal weight, overweight and obese were defined using the BMI percentiles for age developed by the CDC (2018). Normal weight are children that fall between the 5th and 85th percentile on the CDC BMI for age chart. Overweight and obese are children defined as greater than the 85th percentile on the CDC BMI for age chart. Participants qualified for enrollment based on answers to a screening questionnaire regarding compliance with breakfast shake consumption each day, ability to lay still for 30-minute energy expenditure measurements and willingness to fill out 24-hour food record. Guardians were also asked to describe a typical breakfast of the child, children who habitually skip breakfast (>5 times a week) and children who already consume a significant amount of protein (i.e. 25 g pro 4+ days a week) at breakfast were excluded from participation. Exclusion parameters included food allergies, dietary restrictions, prescription medications, claustrophobia, fear of needles, and classification as a "picky eater" by parent or guardian and falling below the 5th percentile for BMI on the CDC (2018) BMI for age charts. In total 112 interested participants underwent an initial phone screening. Among the 57 participants that qualified, 33 enrolled in the study. A total of 22 participants completed the study. 11 participants dropped out due to lack of adherence to the protocol and fear of blood draw. Consent and assent forms were signed upon completion of the screening questionnaire and participants were enrolled in the study.

Dietary Intervention

Test drink nutrient compositions are described in **Table 1** below.

Table 1.

Breakfast Composition

	PRO Breakfast	CHO Breakfast
Energy (kcal)	360	360
Protein (g)	30	13
Carb. (g)	31	48
Fat (g)	11.7	11.7
Fiber (g)	2	2
Palatability	89.2 ± 12.7	76.7 ± 20.2

Palatability Expressed as Mean ± Standard Deviation

Measurements and Data Analysis

Anthropometric Measurements

Body height was measured to the nearest 0.01 cm with participants barefoot, in a free-standing position. Body weight was measured in a fasting state to the nearest 0.01 kg using a calibrated scale. BMI was then calculated by weight divided by height squared and aligned with BMI percentile charts (CDC, 2018) to allow categorization as normal weight, overweight, or obese.

Body Composition

Lean mass, fat mass and percent body fat were assessed using a dual-energy X-ray absorptiometry (DEXA) device (iDXA, 2011) at the Exercise Science Research Center at the University of Arkansas. All body scans were performed by trained technicians. Participants were required to remove all metal for the DEXA scans. Measurements were taken with the participants in a reclined position and were instructed to lay still while the DEXA machine passed over the body.

Energy Expenditure

Resting energy expenditure (kcal per minute) was measured using a TrueMax 2400 metabolic cart (Parvomedics) with ventilation hood via indirect calorimetry. Indirect calorimetry of resting energy expenditure allows measurement of oxygen consumption (VO2), carbon dioxide production (VCO2), and respiratory exchange ratio (RER).

$$RER = VCO2 / VO2$$

(Neumann, Dunn, Johnson, Adams & Baum, 2016) (Cooper, Watras, O'Brien, Luke, Dobratz, Earthman & Scholler, 2009)

The metabolic cart was recalibrated at the beginning of each study day to account for environmental changes such as barometric pressure, humidity, and temperature that could affect measured values. Measurements were taken with participants in a reclined position.

Appetite Assessment

Appetite was assessed using traditional 100 mm visual analog scales (VAS) (Hill, Magson, & Blundell, 1984). VAS scales were used with opposing words ("not hungry at all" vs. "extremely hungry") at timepoints 0, 15, 30, 60, 90, 120, 180 and 240 minutes. Questions asked were: "how full do you feel at this moment," "how hungry do you feel at this moment," "how strong is your desire to eat at this moment," "how much food do you think you can eat at this moment." Participants were asked to place an "X" on the scale to quantify their response at that moment.

Palatability

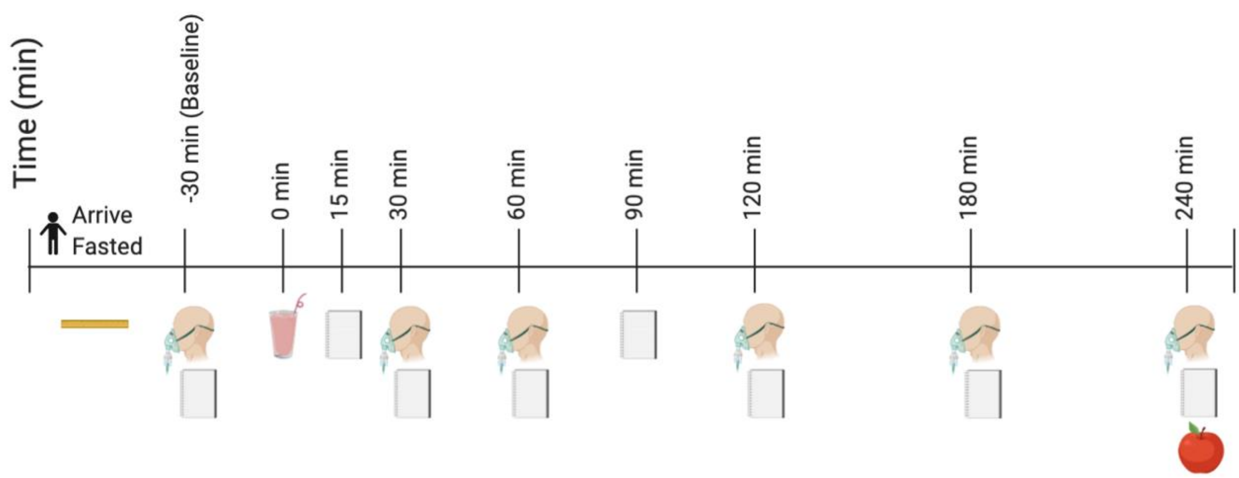
To control for taste preference variability between the groups, palatability measures for each intervention were measured using VAS question "how much do you like the taste of the drink?"

Dietary Intake

Dietary intake was assessed using 24-hour food records to be completed following the treatment breakfast shake. Participants were provided digital scales, measuring cups, and measuring spoons to be able to accurately complete records. This allowed us to measure differences between carbohydrate and protein groups regarding their total energy intake, as well as what comprised their subsequent diet. 24-hr records were then collected and analyzed using Nutrition Data System for Research software version 2018 developed by the Nutrition Coordinating Center (NCC), University of Minnesota, Minneapolis, MN.

Figure 1.

Study Day Timeline



Statistical Analysis

Data were analyzed using statistical software GraphPad Prism 8.3.1. Data was analyzed using either one-way or two-way ANOVA using GraphPad Prism 8.3.1 software with P-value <0.05 being considered statistically significant.

Results

Participant Characteristics

A total of 22 children completed the study. **Table 2** contains participant demographics and baseline anthropometric measurements. There was no significant difference in age or height between weight groups or dietary interventions. As expected, OW participants had significantly higher (p<0.05) BMI percentile, fat mass, and percent body fat compared to NW participants.

Table 2.

Participant Characteristics

	Normal Weight		Overweight/Obese	
	CHO n=7	**PRO n=7**	**CHO n=3**	**PRO n=5**
Age (years)	11.6 ± 3.0	12.0 ± 2.4	12.3 ± 1.50	11.34 ± 2.1
Height (cm)	154.0 ± 14.5	152.2 ± 14.2	151.4 ± 4.1	158.4 ± 17.1
Weight (kg)	45.0 ± 10.9	48.8 ± 29.9	58.1 ± 12.1	69.2 ± 28.5
BMI Percentile	62.1 ± 15.3	37.4 ± 19.5	89.3 ± 8.4****	94.8 ± 3.6****
Fat Mass (kg)	8.6 ± 3.7	7.5 ± 3.1	19.7 ± 14.3**	27.2 ± 16.4**
Lean Mass (kg)	34.2 ± 9.4	29.3 ± 12.3	35.2 ± 12.3	39.0 ± 12.0
Percent Body Fat	20.1 ± 7.1	19.5± 5.2	33.6 ± 17.4***	40.9 ± 6.9***

Data expressed as Mean ± Standard Deviation. ** (P <0.01), ***(P<0.001),***(P<0.0001).

Dietary Assessment

24-hour energy intake and macronutrient composition are shown in **Table 3**. There was no significant effect in total energy intake across groups.

Table 3.

24-hour Food Intake

	Normal Weight		Overweight/Obese	
	CHO n=7	**PRO n=7**	**CHO n=3**	**PRO n=5**
Energy, kcal	1851 ± 686	1764 ± 731	1721 ± 436	2388 ± 868
Fat, g	75 ± 39	67 ± 27	57 ± 27	67 ± 30
Carbohydrate, g	222 ± 72	210 ± 92	238 ± 47	299 ± 141
Protein, g	77 ± 36	84 ± 29	71 ± 8	114 ± 41
Percent Calories from Fat	36%	34%	28%	36%
Percent Calories from Carbohydrates	48%	46%	55%	43%
Percent Calories from Protein	16%	20%	17%	21%

Data Expressed as Mean ± Standard Deviation

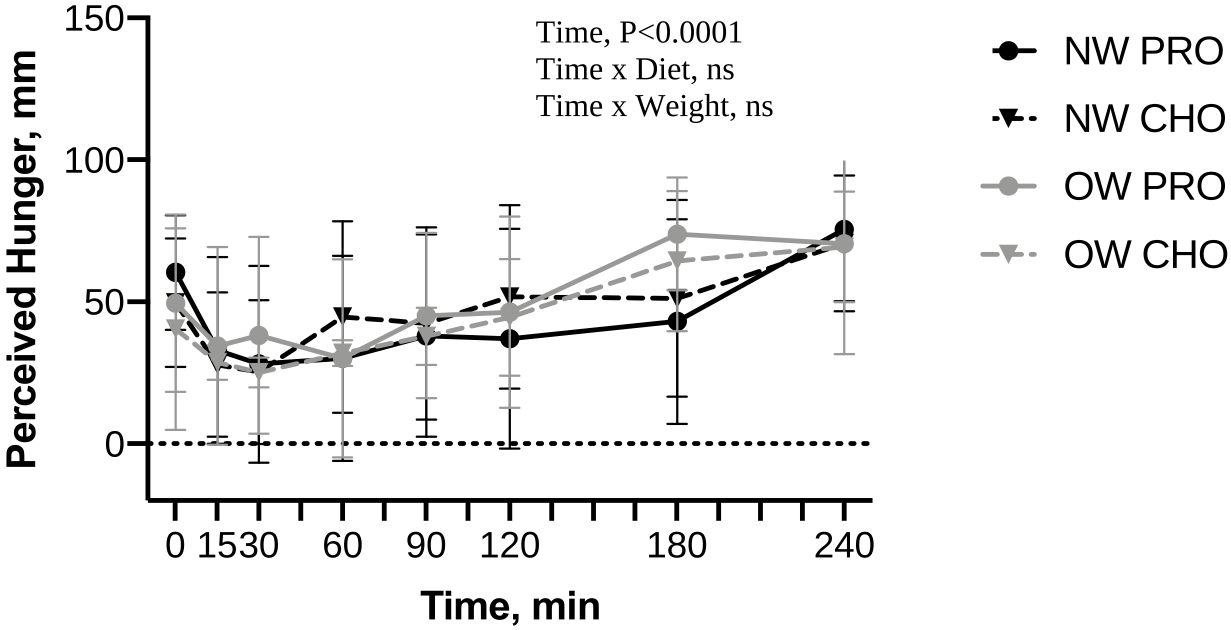
Appetite Assessments

Perceived Hunger and Fullness

Perceived hunger and fullness were measured using VAS scales and are shown in **Figure 2** and **Figure 3.** There was a significant effect of time (P<0.0001) on hunger and a significant effect of time (P<0.0001) and breakfast composition (P=0.0023) on fullness. There was a tendency for overweight participants to be hungrier, and less full than normal weight participants.

Figure 2.

Perceived Hunger



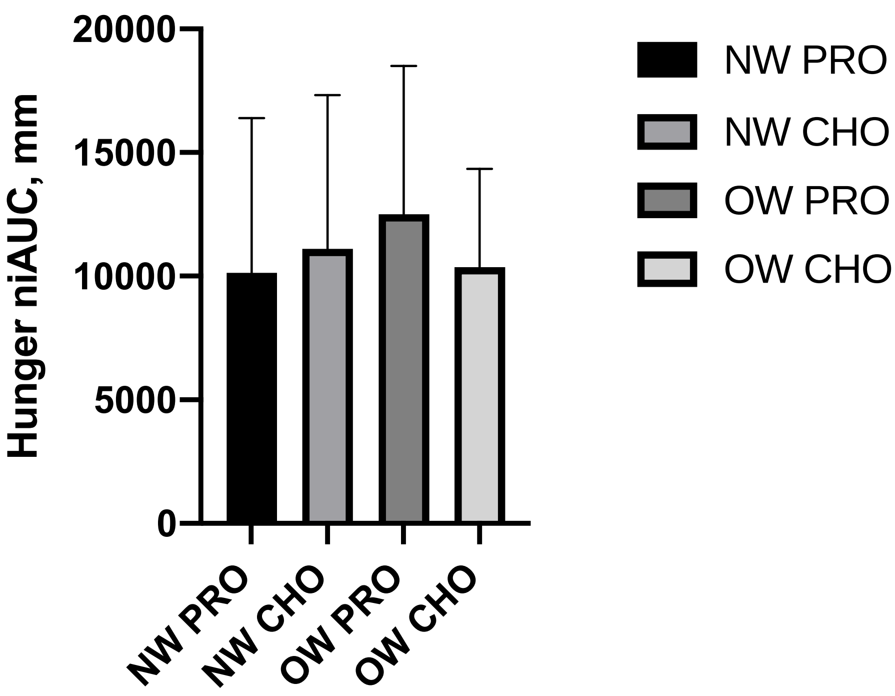


Figure 2. Perceived hunger over 240 minutes postprandial and net incremental area under the curve (niAUC) of normal weight (NW) and overweight/obese (OW) school aged children in response to a protein-based (PRO) or carbohydrate-based (CHO) breakfast.

Figure 3.

Perceived Fullness

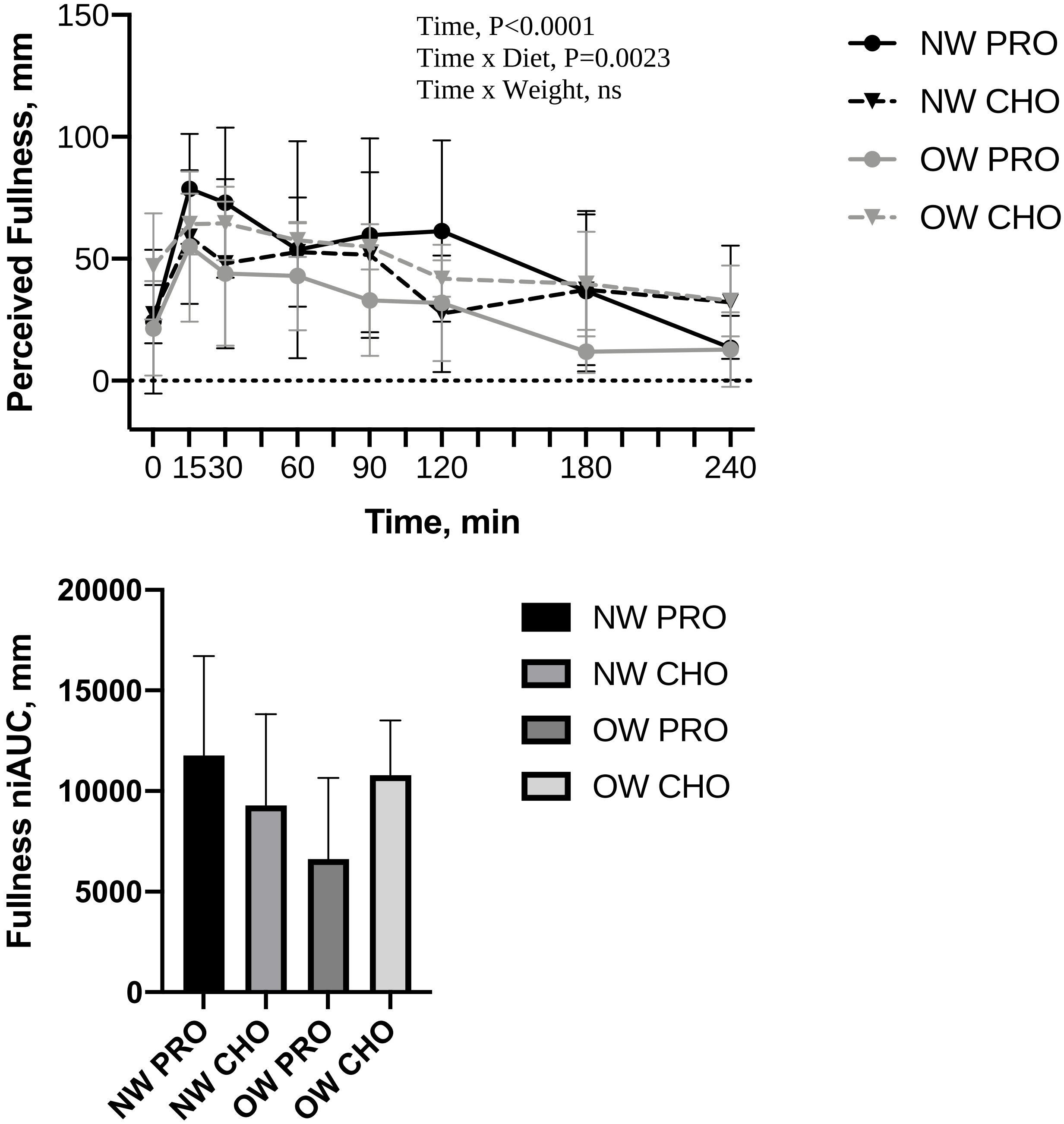


Figure 3. Perceived fullness over 240 minutes postprandial and net incremental area under the curve (niAUC) of normal weight (NW) and overweight/obese (OW) school aged children in response to a protein-based (PRO) or carbohydrate-based (CHO) breakfast.

Strength of Desire to Eat

There was a significant effect of time (P=0.008) on the strength of desire to eat, however no difference was seen between breakfast compositions as seen in **Figure 4.**

Figure 4.

Perceived Strength of Desire to Eat

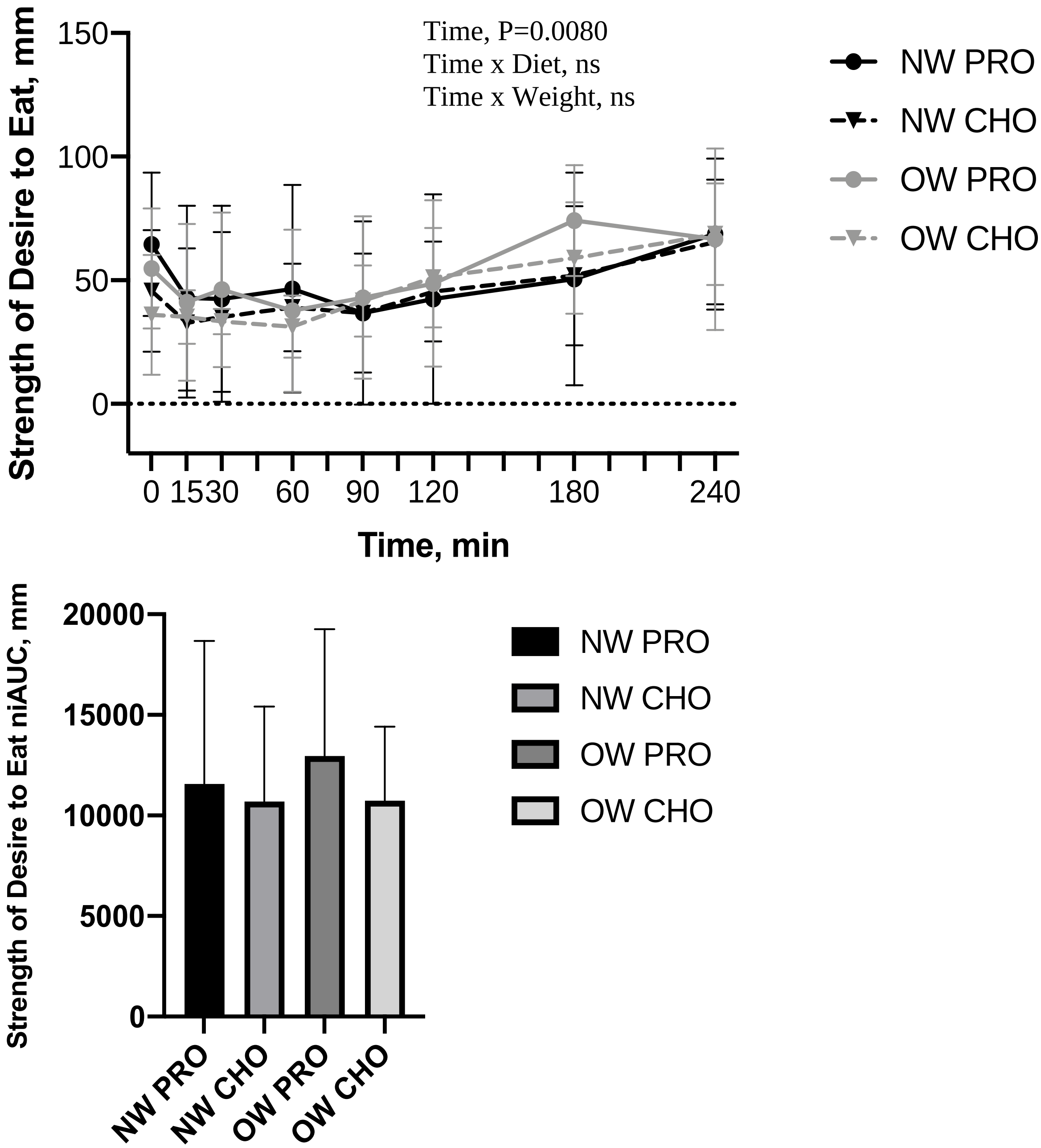


Figure 4. Strength of desire to eat over 240 minutes postprandial and net incremental area under the curve (niAUC) of normal weight (NW) and overweight/obese (OW) school aged children in response to a protein-based (PRO) or carbohydrate based (CHO) breakfast.

Palatability

There was no difference in taste preference between carbohydrate and protein breakfast drinks.

Energy Expenditure

There was a statistically significant difference in energy expenditure between NW PRO and OW PRO (P<0.0001), NW PRO and OW CHO (P=0.0005), NW CHO and OW PRO (P=0.0002), NW CHO and OW CHO (P=0.0093), and OW PRO and OW CHO (P=0.0074). There was also a significant difference in energy expenditure and time (P<0.0001) as seen in **Figure 5.**

Figure 5.

Energy Expenditure

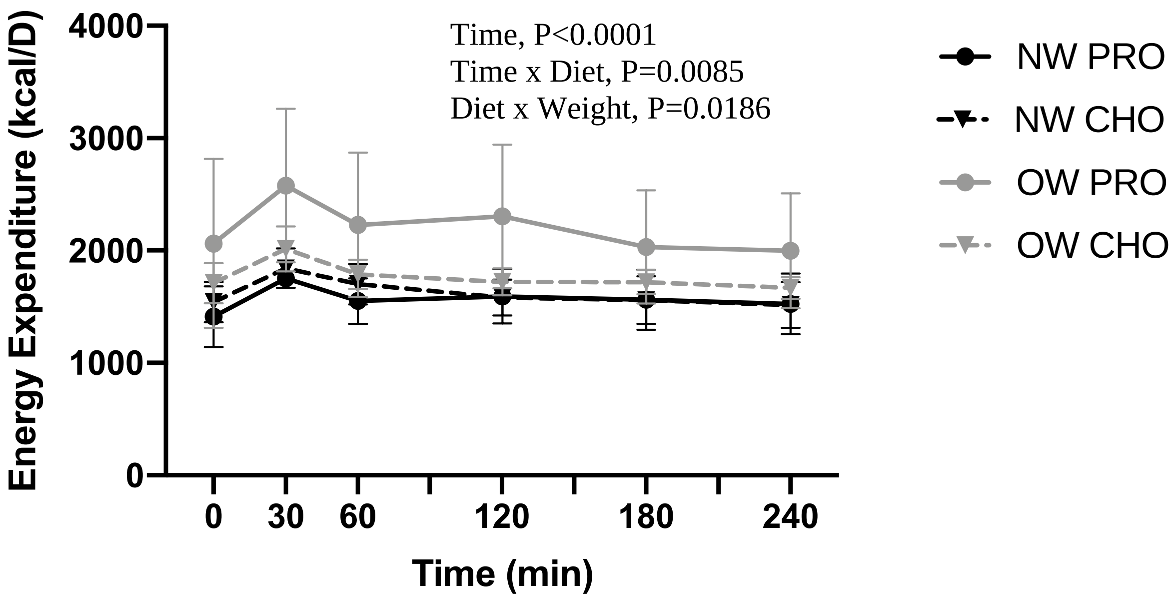


Figure 5. Energy expenditure over 240 minutes postprandial of normal weight (NW) and overweight/obese (OW) school aged children in response to a protein-based (PRO) or carbohydrate-based (CHO) breakfast. NW PRO, n=7; NW CHO, n=7; OW PRO, n=5; OW CHO, n=4.

Discussion

To our knowledge, this study is one of the first to demonstrate that a whey protein-based breakfast may increase fullness and energy expenditure in overweight and obese 7-17-year-old children. This response has been observed in adults, with a higher protein breakfast increasing energy expenditure (Westerterp-Plantenga, 2009), and improving appetite measures and satiety (Ratliff, 2010; Westerterp-Plantenga,2009) but had not previously been investigated in children. Outcomes of one randomized study examined the impact of a low-glycemic index and higher protein combination diet and saw a statistically significant decrease in the percentage of overweight and obese participants compared to other groups, demonstrating that a low glycemic index and higher protein diet may be protective against overweight and obesity for children 5-18 years old. (Papadaki, 2010). Our results show that a protein-based breakfast (30 g) compared to a carbohydrate-based breakfast (13 g) led to increased perceived fullness. Our results in energy expenditure were significant, in that our overweight, protein-based breakfast participants had visibly and significantly higher energy expenditure. Taken together, this data suggests that a protein-based breakfast for school aged children may be important for increasing perceived fullness and energy expenditure, which could contribute to the reduction in childhood obesity via improving energy balance.

Our appetite data is supported by Douglas et al. (2019) who demonstrated, in a study of 37 overweight adolescent girls, that there was no significant effect of macronutrient composition on hunger or strength of desire to eat, but a significant effect for the higher protein breakfast on fullness. Our results show that breakfast composition, body weight, and time influence how full a participant feels following a higher protein breakfast, align with the study conducted by Leidy et al. (2013) which showed increased fullness with a high protein breakfast (35 g protein) in a sample of 20 overweight or obese, late-adolescent girls. An interesting result of Leidy et al. (2013) not seen in our data, is a change in eating pattern for the subsequent day. We saw no significant effect of breakfast composition on energy intake or macronutrient composition of the remaining 24-hour food intake following the breakfast meal. Leidy et. al (2013), however saw that high protein breakfast (35 g) reduced late night high-fat snacking when compared to their other groups. This difference might have been due to a larger sample size by Leidy et al., or possibly the 5-gram difference in protein between breakfast treatments.

Our findings on postprandial energy expenditure are consistent with previous studies conducted in our lab, which looked at 28 normal weight (n=16) and overweight or obese (n=13) children 8-12 years old (Baum, 2015). The 2015 study found that the overweight children consuming the protein-based breakfast had significantly higher postprandial energy expenditure than the normal weight participants consuming the carbohydrate or protein breakfast drink. This seen increase in energy expenditure with a protein-based breakfast is widely accepted in literature and could become important when deciding a course of action for preventing and treating childhood obesity. Our findings support the recommendation for a higher protein composition of a therapeutic breakfast for obesity.

These results did support some elements of our primary hypothesis, in that energy expenditure and perceived fullness are significantly influenced by the macronutrient composition of breakfast. However, further research will need to be carried out to align the role of macronutrient composition of breakfast and perceived hunger and strength of desire to eat in school-aged children.

The correlation between breakfast composition and obesity has been increasingly of interest in recent literature and is a growing area of research. While this study produced significant results, moving forward with research, there is a need for follow-up and repeat studies. One limitation of this study was sample size. It cannot be known whether a difference in protein vs. carbohydrate could have been seen for perceived hunger response due to our limited enrollment. The sample size also limits the generalizability of our findings. Another limitation is our use of a breakfast shake instead of whole foods. For exact calorie equivalence and controls for palatability, breakfast shakes were used, however it is unknown if a whole food treatment would produce different results. Reproduction of the study and variation of the treatment shake to solid food would be beneficial moving forward for the sake of generalizability as well as validation of our result that a protein-based breakfast at therapeutic level, of any consistency, increases energy expenditure and fullness more so than a carbohydrate-based breakfast.

As childhood overweight and obesity increasingly becomes a global health priority, improvements in dietary recommendations for prevention and treatment will be necessary. Disproportionally carbohydrate-based breakfasts, common among school-aged children may contribute to nonoptimal energy expenditure, and therefore contribute to difficulty in weight management. It was hypothesized that the consumption of a protein-based breakfast would increase energy expenditure and decrease appetite and food intake among overweight and obese school-aged children. Based on our findings, the consumption of a protein-based breakfast did improve energy expenditure and increase perceived fullness in school-aged children. Therefore, I would recommend that a breakfast with a significant amount of protein (30 g) be consumed for beneficial effects on energy expenditure and fullness in school-aged children, as seen in this study.

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