Increasing lean protein intake in preschool-age children and assessing effects on cognition and select health outcomes: NPB PR-005831

Principal Investigator: Sibylle Kranz, Ph.D.

University of Virginia

September 22, 2025

Outcomes reported:

1. We expected that children will like the foods prepared for them and consume similar amounts of food (in grams) but potentially less energy on intervention days compared to control diet days (measured in the lab)
2. We also expected children to experience lower feelings of hunger before the lunch or dinner on intervention days and lower average blood glucose levels one hour after the meal.
3. We expected parents to adopt at least one of the recipes into their diet.

Industry Summary

Pork is a lower cost, lean meat compared to other meats commonly consumed by young children. However, due to marketing and federal/state decisions not to offer pork in childcare centers and schools, many families are not aware of the option to replace other meats with pork. This study was designed to obtain pilot data in a small sample of children and their parents to see if a) children like and eat familiar foods that are made with pork instead of other meat (beef) and b) if parents are aware of pork as a healthy meat options and if they start making meals with pork if we provide them with the recipes of foods that their children ate while in our lab. To achieve these objectives, we conducted a randomized feeding trial during which children age 2-5 years old were invited to come to the lab up to six times and stay with us for four hours, during which we played games and exercised with them and also provided a meal and a snack (half of the time usual childcare fare without meat and half of the time familiar foods make with pork (spaghetti

and sauce, sliders, meatballs). We were able to recruit seven children who completed our protocol. Results showed that the parents overall were not often using pork in home cooking. They were interested in our recipes and some tried them at home (see results below). While consuming the meat-containing menu, children had better results in executive function tests, indicating improved cognition. Our plate waste measured dietary intake data showed that during the time in the lab, children consumed more food in grams, but less energy (kcal), they liked some of the food better than the no-meat counterparts, but results were inconsistent. Overall, our study showed that families with young children underutilize pork as a healthy meat option and that children consumed the pork meals while in the lab but this experience did not translate into their home food environment. In conclusion, our results indicate the dire need to further assess the barriers to purchase and use pork in households with young children. Also, the health benefits of consuming pork, such as lowering energy intake while eating the same amount of food, needs to be explored in larger and more diverse studies to allow a general statement as to the potential role of pork in the prevention of childhood obesity. For questions, please contact Sibylle.kranz@virginia.edu.

Key Findings:

- Parents used pork in their usual cooking but not as often as other meats,
- Children consuming pork meals at the lab led to increased consumption of pork
- Providing parents with our recipes increased their positive attitudes towards pork
- On intervention days, children consumed a slightly higher amount of food but lower total energy and better protein density diet compared to control diet days
- Some children had better executive function skills on intervention days compared to control days

Keywords: low glycemic index diet, executive function, preschool nutrition, pediatric nutrition, satiety

Scientific Abstract

The objective of this project was to collect pilot/feasibility data to conduct a cross-over feeding trial to test the effect of consuming meals and snacks made with affordable lean meats on children's' hunger/satiety ratings and blood glucose levels. We recruited a convenience sample of n=7 children 2-5 years old (based on an estimated 20% attrition rate (p-value=0.05, 80% confidence)) from Charlottesville childcare centers and randomized them into one of two study ½ day camps: "control (usual)" and "filling (lean protein)" at the DAN lab (8 am -12noon or 1–5 pm, Saturday/Sunday). Each camp had a cohort of up to three3hildren who consumed one snack and one meal (lunch or dinner) ad libitum at the lab. Meals were developed based on commonly consumed snacks/meals in childcare centers and protein sources substituted with lean pork during intervention days. We measured dietary intake data (plate-waste method), feelings of hunger/fullness before and after each eating occasion (questionnaire), self-reported liking of the foods (Likert scale), and blood glucose levels 60 minutes after the meal (finger stick and glucometer) on each study day. The main caretaker/food preparer for the family was asked to complete a questionnaire designed to assess her/his attitude towards pork and current practices for using pork in food preparation on the first day of the intervention (interviewer-administered at drop off), the measurement was repeated on the last day of the intervention, and (phone administered) two weeks after the conclusion of the intervention. During the intervention, while picking up their child, parents were provided with recipe sheets for the lean meat snacks and meals and encouraged to serve those foods to their family at home. After the intervention, parents were given a small recipe binder with instructions for at least 2 meals and 2 snacks using lean meats and following the CACFP meal patterns. Outcomes: 1) We expected that children will like the foods prepared for them and consume similar amounts of food (in grams) but

potentially less energy on intervention days compared to control diet days, 2) We also expected them to experience lower feelings of hunger before the lunch or dinner on intervention days and lower average blood glucose levels one hour after the meal, and 3) We expected parents to adopt at least one of the recipes into their diet.

Introduction

Although traditionally pork was considered a high-fat meat, changes in breeding and feeding has resulted in lean cuts of pork that provide less fat than most other meats, including poultry. To date, eight different cuts of pork are recognized by the American Health Association as "healthy meats/protein source" (AHA, 2021). The majority of children living in the US consume predominantly high-fat meats or no meat at all, or highly processed "meat products" such as cold cuts. This is significant because many of these meat products have very high levels of sodium and saturated fat, both related to high blood pressure (Wuhl et al., 2023). Furthermore, childhood obesity rates have been increasing and the role of eating a meal that is high in glycemic index (GI, the blood glucose response to a meal) has been established as one contributor to lower satiety and satiation (eating more and more frequently), thus promoting the development of obesity (Baum et al., 2015; Lansigan et al., 2015). Meals with lower GI are generally accepted as being “more filling” because they do not lead to the rapid drop in blood glucose levels as meals with readily available carbohydrates, thus, leading to high glycemic index. Meals with low GI also improve children's cognitive performance (Jirout et al., 2019). In addition, changing intake behavior during early childhood predicts consumption patterns later in life into adulthood (Jirout et al., 2019).

To date, there is a lack of data indicating effective strategies to increase preschooler's liking of lean meats. Also, meats can be very expensive, and it is not known if caretakers of young children realize that lean pork is a very affordable, healthier option to the types of meat products

predominantly used. Thus, not only do eating behavior-related child characteristics (child eating behavior and relationship with food) likely predict lean meat consumption, but external influences, such as the home food environment, household income, and parental nutrition education level are likely important predictors of those characteristics. A primary objective of this study was to assess caregivers' perceptions of lean meat and to better understand household habits related to pork consumption.

A secondary outcome for this study was the measurement of the effect of physical activity on children's blood pressure. Recently is has been established that increasing proportions of children as young as two years old present with high blood pressure, a risk factor for cardiovascular diseases in the short-and in the long-term. Public health advocates recognize that very little is known about the etiology of high blood pressure in youth. To explore the feasibility of reducing the risk for high blood pressure in preschoolers, we examine short-term results of moderate activity, an established lifestyle change improving blood pressure in adults. Measuring blood pressure and blood glucose (with fingerprick), albeit minimally invasive, are accepted standard procedures to establish the physiological pathway by which dietary interventions affect children's nutrition status or health.

Objectives

The objective of this project was to collect pilot/feasibility data to conduct a cross-over feeding trial to test the effect of consuming meals and snacks made with affordable lean meats on children's' hunger/satiety ratings and blood glucose levels. Since parents are the providers of foods for children ages 2-5 years old, it is important to ascertain data on the current attitude towards pork and if that attitude can be altered based on nutrition education and the children being exposed to highly palatable foods made with lean pork. Therefore, the aims for this study

were: a) make a baseline assessment to ascertain the parents' attitude towards lean pork and how often/how they currently use pork for family meals, b) obtain baseline socio-economic data and children's usual eating behavior, and c) to assess if provision of a cookbook with instructions for the intervention days' meals will change the foods served in the home environment 2 weeks after the intervention. The intervention was designed to increase children's consumption of snacks and meals made with lean pork, as a very affordable lean meat, and to measure changes in hunger/satiety and blood glucose regulation in a controlled laboratory setting.

Materials & Methods

Study Design

This study used a within-subject crossover design to evaluate short-term effects of diet and activity context on preschool-aged children's intake and eating behavior. Children participated in up to six laboratory sessions (hereafter "study days") over the study period. Sessions were four hours in duration and scheduled either as morning sessions (08:00–12:00) or afternoon sessions (13:00–17:00) depending on participant availability. This study was approved by the Institutional Review Board for Human Research Study #HSR231601 and registered at clinical trials.gov (#NCT06882252). Each child completed three study days of each of two conditions (total = 6 days per child): intervention diet, control diet The order of the six study days was randomized to minimize order effects. All participants experienced each condition three times, and analyses used the within-participant repeated measures structure to compare outcomes across the different conditions. Meals were developed based on commonly consumed snacks/meals in childcare centers and protein sources substituted with lean pork during intervention days. We measured dietary intake data (plate-waste method), feelings of hunger/fullness before and after each eating occasion (questionnaire), self-reported liking of the foods (Likert scale), and blood glucose levels

60 minutes after the meal (finger stick and glucometer) on each study day. Dietary intake measurements and blood glucose levels were averaged for each diet type and analyzed on the group level (outcome 1+2). ***Parents*** were asked to provide social-economic background information and complete the Children's Eating Behavior Questionnaire (CEBQ) for their participating child to assess picky eating. The main caretaker/food preparer for the family was asked to complete a questionnaire designed to assess her/his attitude towards pork and current practices for using pork in food preparation on the first day of the intervention (interviewer-administered at drop off), the measurement was repeated on the last day of the intervention, and (phone administered) 2 weeks after the conclusion of the intervention. During the intervention, while picking up their child, parents were provided with recipe sheets for the lean meat snacks and meals and encouraged to serve those foods to their family at home. After the intervention, parents had a small recipe binder with instructions for at least 2 meals and 3 snacks using lean pork and following the CACFP meal patterns. Parents were be asked if they included at least one of the recipes in their home food environment and to report any barriers (outcome 3). One additional question was focused on the desirability of having recorded recipe preparation videos available to increase the use of the recipes.

On each study day, children were provided one meal and one snack ad libitum in the laboratory. Standardized protocols were used for food presentation and timing across all study days. Between eating sessions, children participated in play sessions that were either structured or unstructured based on the day's assigned activity condition. Parent/guardian arrivals and departures were timed consistently, and any protocol timing deviations were documented.

Primary and secondary measures collected on each study day included food intake, subjective hunger/fullness, food liking, cognitive (executive function) assessments, blood

glucose, and blood pressure. At the first study day, participants participated in height and weight measurements, along with questionnaires about demographic information and the Child Eating Behavior Questionnaire (CEBQ). Subjective hunger/fullness was conducted by completing brief, age-adapted ratings of hunger and fullness collected immediately before and after each eating occasion. Food liking was self-reported liking recorded after consumption using a scoring system of –1 (dislike), 0 (neutral), and 1 (liked). Participants had their blood glucose and blood pressure taken in the last hour of their study visit. Participants also completed cognitive assessments during each study visit. These assessments included four cognitive function assessments that are perceived by children as games: "Happy/Sad," "Track-It," "Peg Tapping," and Kansas Reflection-Impulsivity Scale for Preschoolers (KRISP). KRISP and "Peg Tapping" were completed after the first meal, "Happy/Sad" and "Track-It" were completed after a second meal and quiet (nap) time.

On Day 1, informed consent was obtained from parents/guardians. Parents complete the Child Eating Behavior Questionnaire (CEBQ) and a socioeconomic status (SES) questionnaire. Child anthropometrics (height, weight, and BMI) were measured, and the hunger/fullness scale was introduced using a story-based explanation appropriate for preschool-aged children. A pork attitude questionnaire was administered to parents on both Day 1 and Day 6. On Day 6, follow-up contact information was also collected. Most parents left the lab to wait for their child in a separate room with internet connection across the hall from the lab. After a short acclimation period to get children used to the researchers and the lab the lab day schedule commenced:

- Arrival and Snack (8:00-8:30): snack is served and children complete a food liking questionnaire
- Activity 1 (08:30-09:00): Free play (control) or structured physical activity (intervention).
- Learning 1 (09:00–09:30): Cognitive tasks (KRISP and peg tapping).
- Activity 2 (09:30–10:00): Free play or structured activity.

- Lunch (10:00–10:45): Standardized meal with intake weighed and recorded, pre- and post-meal hunger/fullness ratings, and liking assessment.
- Rest (10:45–11:30): Quiet reading or rest time.
- Learning 2 (11:30–11:50): Cognitive tasks (Happy/Sad and Track It), along with blood glucose and blood pressure assessments.
- Wrap up (11:50-noon) parent sign-out, and parent pick-up.

Results

Participants

Seven children (n = 7) participated in the study. At enrollment, their ages ranged from 28 to 73 months (mean = 48.4 months, SD = 15.0), corresponding to approximately 2 years 4 months to 6 years 1 month. Individual participant ages were 28, 36, 46, 46, 48, 62, and 73 months. The sample included both male (n = 4) and female (n = 3) participants. All children were able to consume study foods without dietary restrictions. Families were recruited from the local community, and written informed consent was obtained from parents or legal guardians prior to participation. Participants also verbally assented to their participation in each study task.

Pork Attitude Questionnaire & Recipe Reports

Parents of the participants were asked to rate their attitude towards pork on a 7-point scale (1 indicating that they absolutely did not like pork, 7 that they enjoyed eating pork very much). After providing a rating, they were asked to elaborate on their attitude towards pork. Parents were asked to evaluate their pork attitude at three different times throughout the study: at pre-intervention (day one), at post-intervention (day six), and at the follow-up period (two weeks after the intervention took place). On the post-intervention and follow-up surveys, parents were also asked if they tried any of the recipes provided in the lab and if their families enjoyed them.

The purpose of the pork attitude questionnaire was to assess changes in pork enjoyment throughout the study, facilitated by exposure to new recipes in the lab.

At pre-intervention, parents reported an average of 5.429 on the pork attitude scale. Parents of participants 3, 6, and 7 all reported a 7 at pre-intervention; they all ate pork regularly and expressed enjoyment in eating it. Parents brought up various forms of pork that they regularly prepared and that their children also enjoyed, including pork sausage, bacon, pulled pork, and pork tenderloin. The lowest score reported among the parents was three. When asked why, this parent reported that they do not enjoy cooking meat and that they were trying to minimize their child's red meat intake.

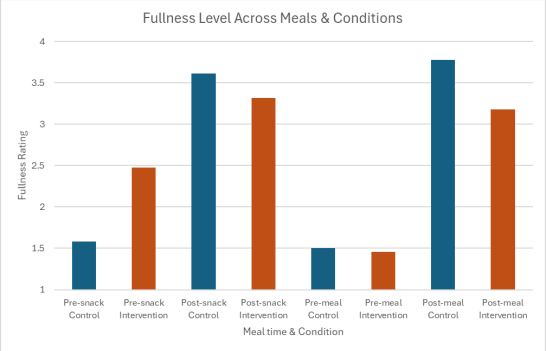
At post-intervention, the average response of 5.429 matched the pre-intervention average. However, several parents' responses did change, with the parents of participants 1 and 4 reporting a more positive pork attitude than before and with the parents of participants 2 and 3 reporting a more negative pork attitude. All liked eating pork at least to a moderate degree, but practical obstacles such as lack of time, cost of the meat, or not enjoying the process of cooking pork were various reasons given for why scores did not increase. These were also the reasons parents reported for not having tried the recipes provided in the lab.

When asked again at the follow-up period, the average answer decreased slightly to 5.286. Five of the families said that pork was regularly included in their diets, but that they were inclined to choose other meat options at times for various reasons (i.e., having variety in their diets, cost-effectiveness of other meats such as chicken). One parent reported that they had made a recipe provided from the lab at this point; those that had not used the recipes cited reasons such as having limited time to cook during the week or already using similar recipes in their routines that they preferred. Responses to the pork attitude questionnaire indicate that simply enjoying

pork may not be enough of a reason for parents to regularly eat it or provide it to their children depending on the conditions within their household.

Food Intake Questionnaire & Self-Rated Fullness

On each study day, parents were asked if their child had eaten anything prior to arriving at the lab. Across all participants and all study days, 100% of parents reported that their child had eaten before arrival. Participants were also asked to self-rate their fullness level before and after they ate snacks and meals on a 4-point scale (1 meaning very hungry,4 very full). Ratings were provided right before and right after participants were served their food. The graph below (Figure 1) indicates how satiety changed over time and differed by condition. There was a two-hour gap between the post-snack and pre-meal fullness levels. Results show that on intervention days, children felt on average less full after the meal but pre-meal ratings were similar. Although the children were randomized, the pre-snack level of fullness was higher in the intervention group, indicating a systematic effect on subsequent measures. **Figure 1.**



Food Liking Responses

Participants were asked to report how much they liked each food that they consumed throughout the study using a smiley-face visual scale with three categories (dislike -1, neutral 0, or like 1). Many foods served to participants had multiple components (i.e., spaghetti served with tomato sauce or meatballs with two different dipping sauces) and children were asked to report their enjoyment of each component individually. The graphs below indicate the snacks (Figure 2)

and meals (Figure 3) that were served and indicates the level of enjoyment for each food across all of the participants.

Figure 2.

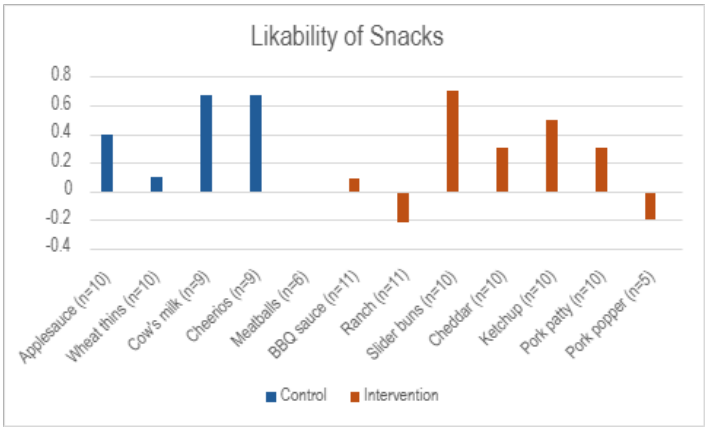
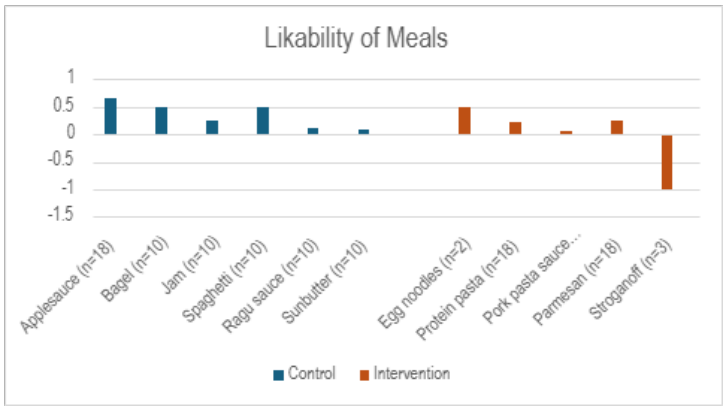


Figure 3.



Participants ate many of the same foods multiple times throughout the study. The graphs below indicate how participants' food liking responses changed across time for the snack items (Figure 4) and meal items (Figure 5) that they ate more than once.

Figure 4.

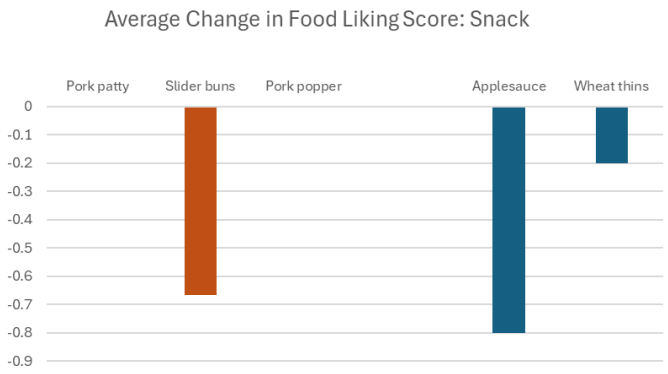
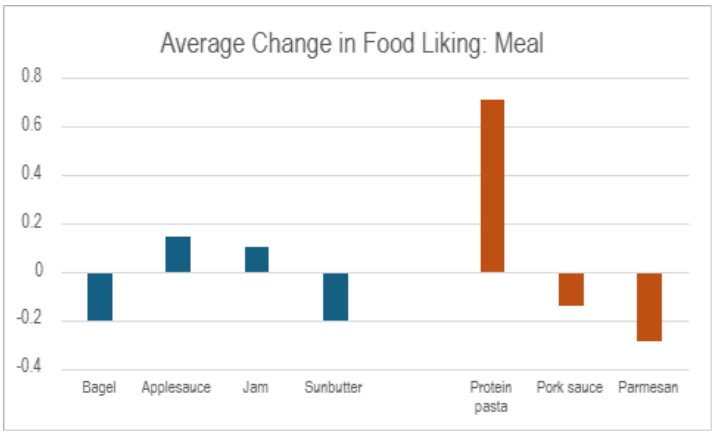


Figure 5.



The purpose of assessing change in food liking scores over time was to better understand how repeated exposure to the same food can change children's responses to that food. These results indicate that responses to different foods changed over time, and further study would be beneficial to understand the nature of these changes.

Blood Pressure

Blood pressure assessments were completed in the last thirty minutes of each study day. These assessments involved three consecutive measurements with an automatic blood pressure machine. Of the seven participants, three completed all blood pressure assessments during the study duration. Two participants refused on five study days and participated only on one study day. These participants both refused to complete the second and third blood pressure measurement, so the average could not be taken of three measurements. One participant (age 2)

refused a singular blood pressure assessment during an intervention day. Another participant refused the any blood pressure measurements on the first and the last day of the study. In total, this provided 14 average blood pressure readings from non-intervention days, and 16 readings from intervention days.

The non-intervention days had an average systolic blood pressure of 92 mmHg and an average diastolic blood pressure of 59 mmHg. The intervention days had an average systolic blood pressure of 97 mmHg and an average diastolic blood pressure of 63 mmHg. From this, it appears that the intervention days had an increase in blood pressure, despite significant barriers to data collection.

Blood Glucose

In a pattern similar to the blood pressure assessments, many participants refused some or all data collection. Only two of seven participants completed all blood glucose measurements in the duration of the study. Of the remaining five participants, three participants completed a single blood pressure measurement, one participant completed three blood glucose measurements, and 1 participant refused all blood glucose measurements during the study. This yielded eight blood glucose data points from non-intervention days and 10 blood glucose data points from intervention days.

The non-intervention days had an average blood glucose measurement of 106.9 mg/dL, and the intervention days had an average blood glucose measurement of 107.8 mg/dL. The blood glucose difference of <1 mg/dL was small difference, with a slight increase on the non-intervention days.

Caloric & Protein Intake

The graphs below indicate the average daily calories consumed (Figure 6) and the average daily weight in grams (Figure 7) of the foods that participants ate on intervention days and control days.

Figure 6.

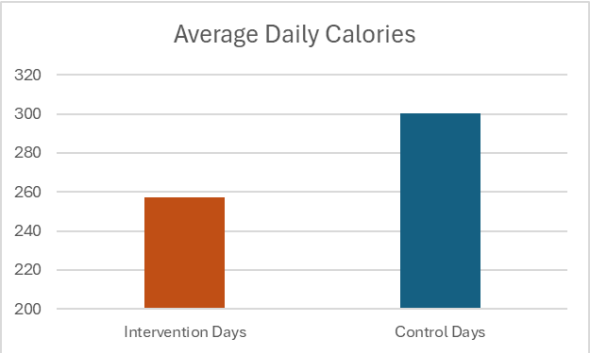
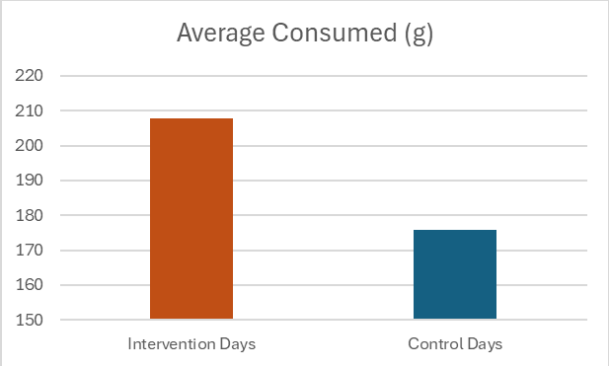


Figure 7.

Average Consumed (g)



On intervention days, participants consumed more in grams but less in calories, which corresponds with the lower satiety they experienced on intervention days. Despite fewer calories, participants on intervention days consumed very similar amounts of protein and experienced very similar energy density levels compared to the control days. The graphs below indicate differences in protein intake (Figure 8) and energy density (Figure 9) between the conditions.

Figure 8.

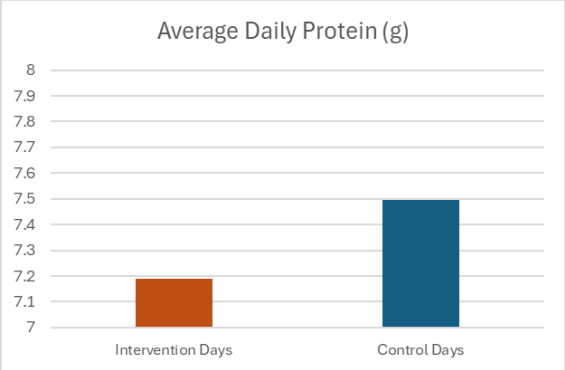
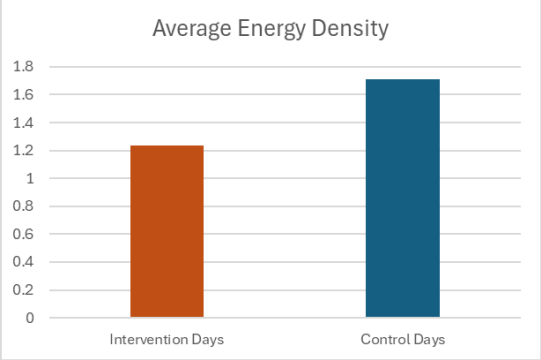


Figure 9.



Learning Outcomes

Participants completed a series of cognitive tasks in the lab to assess how the diets interacted with cognitive processing. Table 1 provides an overview of the sample size of children who completed the test at each age. Since age is a large factor in cognitive performance tests, additional analysis will be conducted. Presented here are the raw data for all children combined. Participants made fewer errors on the KRISP task on intervention days (Figure 10), but there were minimal differences between scores in the peg tapping task (Figure 11) and the Track-It task (Figure 12). Data from the "happy-sad" short-term memory will be added in the future.

Table 1.

Number of trials of each cognitive task by participant age

Task	Age 2	Age 3	Age 5
KRISP	n=8	n=16	n=12
Peg Tapping	n=7	n=18	n=12
Track-It	n=9	n=18	n=12
Happy/Sad	n=8	n=16	n=12

Figure 10.

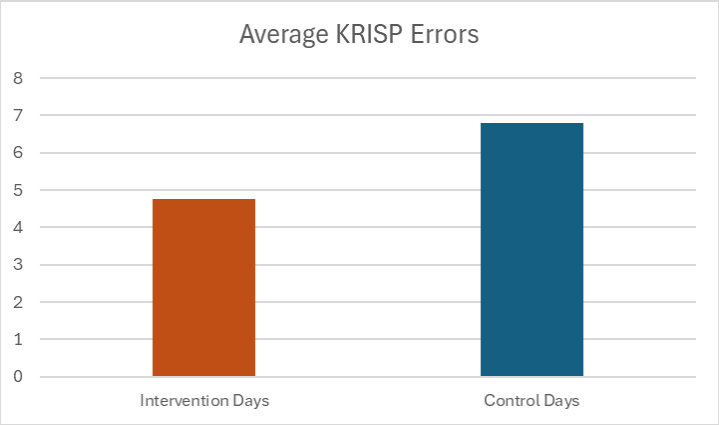


Figure 11.

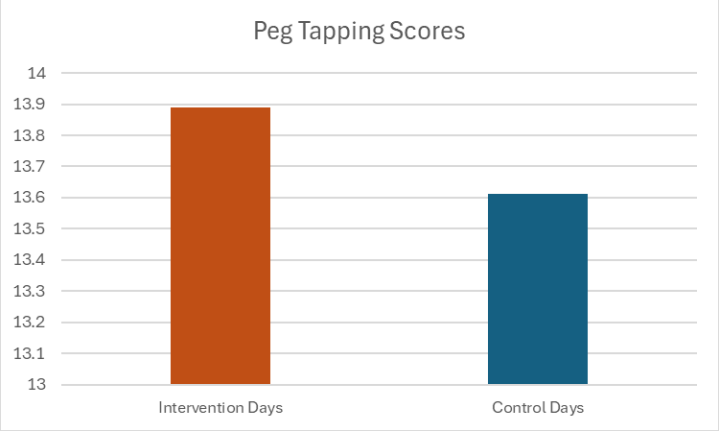
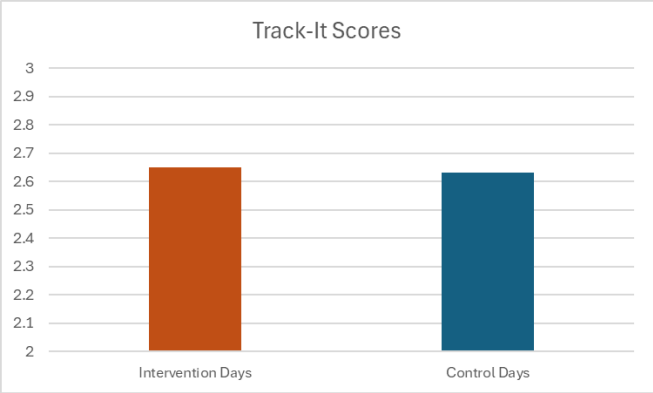


Figure 12.



Discussion

This study was conducted to examine if children are willing and like eating familiar dishes that are modified to contain lean pork and to explore parent's attitudes towards pork and if children's consumption of meals containing pork (and provision of the recipes) would increase consumption of pork at home. Results of our study indicate that pork is underutilized by families with young children. Although children consumed more grams of food during meals and snacks on intervention days, their energy consumed was reduced which resulted in higher protein density compared to control-diet days, indicating a potential role of pork-containing meals on the prevention of childhood obesity. Preliminary analysis indicates a potential relationship between the higher protein consumption days with cognitive tests results, measuring executive function skills, such as short-term memory, focus, and concentration. We found that children were not familiar with the taste and texture of pork in several of the dishes and repeated exposure might be needed to increase the liking of those foods. We also saw that although some of the parents already used pork in home cooking on occasion, two sets of parents did not, and they reported one main barrier (don't want to cook with raw meat).

Several limitations in this study must be noted. First, due to the increase of inclement attitude towards scientific research in the local community, recruitment was much lower than anticipated based on our previous year's research. Thus, our sample was reduced to only seven children and their families with ages ranging from two to five years old, a major disadvantage in the interpretation of results, since toddlers are in a very different developmental stage compared to five-year-olds. Although we extended the study duration, we were not able to increase participation rates by more than three additional children. Although this was a very disappointing outcome of our recruitment efforts, experiences from colleagues in the School of Education and Human Development at UVA mirror our experience. Future intervention study attempts will benefit from a preliminary market research on parent's attitude towards participating in research studies. A second, related limitation was that we had children between 2-5 years old as participants, which means we only had a very small sample in each age band, reflecting the developmental stage of the children. Usually 2-3, 3-4, 4-5 year old children can be combined for analysis but our sample sizes were still too small.

Despite these challenges, we are currently writing a manuscript for the journal "Pilot and Feasibility Studies" to share the development of the protocol, the challenges encountered and to present select pilot data to help other researchers in the field of pediatric nutrition to successfully complete nutrition intervention studies. We anticipate that the manuscript will be submitted by December 2025. One additional positive outcome of this research was the large engagement of undergraduate students in this study. Fifteen students completed all of the required training and were added to the IRB protocol to aid in data collection. Three of these students are still actively involved with data entry, data analysis, and the development of the manuscript. They will be co-authors on the paper.

Overall Main message: Marketing to increase awareness could be very effective in increasing interest of parents with young children to add pork as a healthy meat option in their children's diet. This study was too small to make general statements but repeating this design in studies with larger and more diverse populations, especially with more children in each age band (2-3 year olds, 4-5 year olds) would be critical to further explore the trends we observed in this small convenience sample.