INTRODUCTION

Low fruit and vegetable (FV) intake in childhood is correlated with increased risk for disease later in life.[1] Food behaviors established in preschool years (ages 3-5) can determine long-term dietary quality, including adequate intake of FVs.[2] Unfortunately, children from low-income families are at disproportionally higher risk compared to the general population for low FV intake and associated diseases, including obesity.[3] Numerous interventions and policies have directed efforts to improve low FV intake among children, particularly in early childcare environments.[4,5] Encouraging young children to try new foods can be challenging since child neophobia, or "fear of the new", is prominent during preschool years.[6] Decreasing neophobia for vegetables, in comparison to fruits, is more difficult because children have a predisposition to favor fruits due to their natural sweetness.[2] Ten to 15 exposures have been cited as necessary to positively influence preference and intake, where 'exposure' is generally accepted as any interaction or observed interaction with a given food.[2] Exposing children to foods through hands-on, food-based learning (FBL) has been demonstrated as one way to effectively increase exposures[7] while allowing children to explore FV outside of the mealtime environment.[8] Interventions adopting a FBL approach to increase exposure to healthy foods also show promise in increasing later FV consumption.[5,8]

With over one million low-income children enrolled each year,[9] Head Start (HS) makes an ideal setting for interventions targeting FV intake. However, while programs like HS are interested in the nutritional outcomes of the young children they serve, their priorities also include meeting school readiness goals.[9] Of the studies that have demonstrated use of FBL as a method to impact preference and consumption, to the authors' knowledge only one study[5] has also explored the integration of food-based activities with Science, Technology, Engineering, Art, Mathematics (STEAM) learning as a method to improve children's FV intake. Integrating a FBL approach with STEAM represents a unique opportunity for preschool teachers to both engage children in learning across multiple school readiness domains while exposing children to new foods and nutrition education. Preschool teachers face many barriers in the classroom, including time constraints and competing priorities, which may impact the quantity and quality of nutrition education provided.[10,11] Integrating STEAM and FBL has been cited by HS teachers as one approach to reducing the these barriers[10,12], however limited research is available to determine if integrating FBL and school readiness concepts also has the potential to positively impact children's FV intake. Therefore, the purpose of this study was to assess the effectiveness of STEAM FBL activities on HS children's liking of nine target vegetables and overall FV intake. It is hypothesized that vegetable exposure through STEAM FBL activities would significantly increase vegetable liking and overall FV intake compared to the control group.

METHODS

Eleven classrooms (6 intervention, 5 control) in three Eastern North Carolina HS centers participated in this quasi-experimental study during the 2018-2019 school year. Parents/guardians and their children were recruited for participation through school registration, parent meetings, flyers sent home, and pick-up/drop-off times. To participate in this study, children were required to be 3-5 years old, enrolled in a participating HS center, and have written consent from their parent/guardian. Children were excluded if they had identified disabilities and/or did not speak English. The [Blinded] University and Medical Center Institutional Review Board granted approval for the study (UMCIRB # xxx-xxxx).

The intervention consisted of seven hands-on, STEAM FBL activities, implemented once a week (October-January), to expose children to nine target vegetables: broccoli, cauliflower, spinach, radish, sweet potato, cucumber, tomato, carrot, and pea pod. Target vegetables were selected based on prior exposure, as determined by parent report, and/or the potential of the food to influence skin carotenoid status (SCS). FBL activities used a STEAM approach that aligned with HS Program Performance Standards[9] and North Carolina Foundations for Early Learning.[13] Each activity lasted approximately 15-20 minutes and included circle time (group discussion) and a hands-on activity highlighting a science, mathematics, and/or language arts concept (**Table 1**). Eight trained Research Assistants delivered all activities to ensure fidelity in the delivery of the intervention.[14]

Data were collected from parents at baseline and from children at baseline (September 2019), midpoint (December 2019), and post-test (February 2020). At baseline, parents were asked to complete three questionnaires addressing (1) basic demographics, including food allergies, (2) child neophobia, and (3) child likes/dislikes/exposure. Parents reported their child's likes/dislikes on a 6-point hedonic scale from "he/she loves it" to "he/she hates it" designed after the *Preschool Adapted Liking Survey*.[15] The survey was adapted to include the nine target vegetables and used photographs identical to those in the child liking tool to ensure parent and child ratings could be compared.[16]

Researchers collected vegetable liking and SCS from children at each of the three timepoints (baseline, midpoint, and post-test). Researchers assessed children's FV liking by modifying a previously validated pictorial FV measure for preschool children. Modifications included the nine target vegetables and other commonly consumed food items for this age group (e.g. hotdog, yogurt).[17,18] The tool includes a non-gendered 5-point face scale ("super yummy" to "super yucky"). All photographs used in the pictorial tool were cognitively evaluated by HS children (n=200) in June 2018. Children's SCS was measured using the Veggie Meter®

(Longevity Link Corporation, Salt Lake City, UT), a non-invasive, quick and objective indicator of skin carotenoid status, and a valid approximation of FV intake.[19] After sanitizing the fingers, children were instructed to insert their right finger into the Veggie Meter®. The Veggie Meter® took three measures and provided an average of the measurements which was assigned as the child's SCS measure.

Data Analysis

Researchers used SPSS (version 25.0 IBM Corp, Armonk, NY, 2017) for statistical analysis. Categorical data are presented as n (%) and continuous data as means (±SD). Mean scores on child-reported liking scores and Veggie Meter® were calculated at baseline, midpoint, and post-test. Tests of significance using independent *t* tests with were conducted to determine differences between baseline and post-test scores within groups. Categorical measures were calculated and compared using independent-samples Mann Whitney-U and related-samples Wilcoxon Signed Rank tests. Repeated measures ANOVA was performed to examine the effect of time at the three time points and intervention on child-reported liking scores and SCS. The dependent variables were change in child-reported liking scores and SCS (two separate models) and the independent variables were sex, age, baseline body mass index, and intervention versus control. A scatter plot was performed to compare change in time across classrooms and revealed similar changes over three time points, therefore researchers did not cluster children within classrooms. Differences were considered statistically significant at $p < .05$.

RESULTS

A total of 113 children (Intervention (I)=49; Control (C)=64; 6.60±3.40 children/classroom) participated in the study. Children were 57% male, an average age of 3.69±0.57 years at baseline, and predominantly Black/African American (81%) followed by Hispanic (6%). No major food allergies were reported. There were no significant differences between groups at baseline for demographics or primary measurements, including body mass index (I=16.94±2.55; C=16.93±2.36; p= .97), level of parent reported neophobia (I=3.87±1.27; C=3.90±1.44; p= .97), SCS (I=267.16±100.22; C=265.03±67.53; p= .89), or target vegetable liking (I=3.18 ±1.04; C=3.15±1.07; p= .90). Attendance among children varied during the intervention; approximately 38% of children attended 6 or more activities, 49% 4-5 activities, and 13% of children 1-3 activities.

Parent-reported target vegetable exposure for both groups is reported in **Figure 1**. Children in both groups had the highest reported exposure to broccoli (I = 95.9%; C= 95.3%) and carrot (I= 93.9%; C=96.9%) and the lowest reported exposure to radish (I = 40.8%; C= 31.2%). Repeated measures ANOVA determined that a time-by-group interaction was not significant for target vegetable liking ($F(2,68)=0.82$; p=.44, r=.02) (**Figure 2**). Although not significant, a decrease in liking for the intervention group over time was observed. SCS levels were significantly higher in the intervention group at post-test compared to the control ($t(85)=2.54$; p= .01) (**Figure 3**). Repeated measures ANOVA determined that a time-by-group interaction was also significant for change in SCS ($F(2,76)=3.98$; p=.02, r=.10). SCS declined in both groups (I=0.06%; C=15.09%) baseline to post-test with a significantly smaller decline observed in the intervention group (P = .02).

DISCUSSION

This study used STEAM FBL activities in HS classrooms, with the goal of increasing children's liking of nine target vegetables and overall FV intake. A STEAM-based learning approach has the potential to prepare children for kindergarten, while also having a positive influence on children's dietary intake.[4,5,20] However, limited evidence is available to understand how STEAM FBL may impact preschool children's liking and intake of FV.[5] Findings from the current study revealed STEAM FBL activities do not appear to improve liking of FV, but did have a positive effect on SCS levels of exposed HS children over the course of the intervention.

Both the intervention and control groups demonstrated an overall decline in liking of target vegetables, however one study has reported preschool children's vegetable liking may decrease before increasing.[21] It is possible children's liking of vegetables in the intervention group may have increased with a longer study duration. Another consideration is the number of vegetable exposures children experience; it is commonly cited that 8-12 taste exposures may be needed to increase liking of a *new* vegetable[22,] however there is limited research to support our understanding of how children's liking for familiar vegetables evolves. The majority of the children in the current study had already been exposed to target vegetables at home or school (**Figure 1**). Prior research has indicated improving liking for novel vegetables may be easier compared to familiar vegetables since no prior exposure or predisposed disliking exists.[23] While selecting novel vegetables for a food-based intervention might allow researchers to assess change in liking more easily, long-term intake of these vegetables could be impacted if children do not have access to them outside of the learning environment. More research is needed to understand how liking for familiar FVs changes over time and its' relationship with actual consumption.

STEAM FBL activities appeared to have had a significant effect on children's FV intake as approximated by SCS. Children in both groups experienced an increase in SCS between baseline and midpoint data collection. However, this was followed by a decline in SCS from midpoint to post-test in both groups with children in the intervention group experiencing a significantly smaller decline compared to the control group. Between midpoint and post-test, participating children were out of school on winter break for approximately three weeks. Prior research has indicated that children enrolled in HS may not have the same access to FV at home compared to school[3] which may account for the drops in SCS levels observed. The smaller decreases in SCS levels observed in the intervention group may suggest intervention children were consuming more carotenoid rich FVs during and after the intervention when these foods were available for consumption. More research is needed to explore these differences including an assessment of home exposures, particularly during periods when children do not have access to school meals.

The study has several limitations and strengths. First, due to the small sample size, the results should not be generalized to children and HS classrooms not included in this study. Due to the non-randomized nature of the study design, results are not immune to selection bias. Future studies should attempt to replicate these findings using a randomized controlled design with larger sample sizes in each group. To the authors' knowledge, no US studies have examined the relationship between preschool children's FV consumption and seasonality. However, prior international studies suggest that seasonality may also impact children's consumption of FV.[24] Finally, no assessment of FV exposure occurring outside of the school environment was measured. Strengths include working with centers affiliated with a single HS program. This partnership helped researchers ensure children from all 11 classrooms generally received the same menu items during the course of the intervention. Additionally, measurement of skin carotenoids allows more objective quantification of consumption compared to mealtime observations or parental reports.[16] Finally, although the Veggie Meter® has been validated[19], few studies have been published using SCS to assess FV intake among preschool-aged children.[19,25]

IMPLICATIONS FOR RESEARCH AND PRACTICE

Aligning FBL and STEAM-based learning activities may present a unique opportunity to impact FV consumption, while also meeting academic standards. Researchers and practitioners developing FBL programs may consider embedding STEAM-based content into their approaches to decrease well described teacher barriers;[10] however, careful consideration of the integration of food-based learning is warranted to understand the level of exposure needed for more familiar vegetables. Because HS teachers are strongly encouraged to participate in FBL, and prior research acknowledges their influence on children's dietary intake,[26,27] aligning evidence-based strategies for FBL into teacher trainings could also be explored.[8] Finally, environmental changes should be considered in an effort to increase exposures and overall impact on children's FV liking and intake. A multi-level approach to FBL on children's vegetable consumption should be incorporated to integrate support from parents, teachers, and administrators.[4] Future studies could explore the incorporation of 1) meals/snacks aligned with vegetables used in FBL, and 2) professional development educating teachers about modeling and positive talk during FBL and mealtimes.[28]

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