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Use of the Veggie Meter® as a tool to objectively approximate fruit and vegetable intake among youth for evaluation of preschool and school-based interventions

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The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained.

Conflicts of Interest:
No conflicts of interest

Abstract

Background: Reflection spectroscopy is an emerging, non-invasive objective measure used to approximate fruit and vegetable intake. The purpose of this study was to use a reflection spectroscopy device (the Veggie Meter®) to assess skin carotenoid status in preschool, middle, and high school students and to examine associations between skin carotenoids and self-reported dietary intake.

Methods: In Fall 2018, we used the Veggie Meter® to assess skin carotenoids, and age-appropriate, validated dietary assessment measures to approximate fruit and vegetable (FV) intake. Preschool participants completed the previously validated Pictorial Liking Tool using an iPad. Middle school participants completed selected questions from the validated School Physical Activity and Nutrition (SPAN) questionnaire regarding frequency of their FV and beverage intake on the previous day, with additional questions about physical activity. High school participants' FV intake was assessed by the National Cancer Institute (NCI) Fruit and Vegetable Screener. Spearman correlation coefficients were used to determine bivariate associations between measures of dietary intake and Veggie Meter®-assessed skin carotenoid levels.

Results: Mean (SD) Veggie Meter® readings were 266 (82.9), 219 (68.1), and 216 (67.2) among preschool, middle-, and high-school students. There was an inverse association between soda intake and Veggie Meter® readings ($r = -0.22$, $p = 0.03$) among middle-schoolers; and a positive, marginally significant association between daily fruit intake and Veggie Meter® readings ($r = 0.25$, $p = 0.06$) among high schoolers.

Conclusions and Implications: The Veggie Meter® is a promising evaluation tool for preschool and school-based nutrition interventions.

Keywords

Skin carotenoids; rural youth; fruit and vegetable consumption

INTRODUCTION

Fruit and vegetable (FV) intake reduces risk of chronic diseases as well as premature mortality. ([1]) However, the majority of the United States (US) population does not consume recommended amounts, with approximately 80% of children ages 2–3 years and 92% of children ages 4–8 years not consuming recommended amounts of vegetables. ([2]) This is particularly concerning because dietary patterns that are established during childhood and adolescence are likely to continue into adulthood. ([3]) Countless preschool and school-based interventions and policies have been developed to promote FV intake among youth. ([4,5]) However, evaluation of such interventions typically relies on self-reported FV intake, which is susceptible to various forms of bias. ([6,7]) Therefore, a valid, reliable, and objective measure of FV intake is needed among youth, to determine effectiveness of school-based interventions and policies.

High performance liquid chromatography (HPLC) analysis of plasma carotenoids is currently seen as the gold standard to objectively assess FV intake. ([8,9]) However, HPLC analysis of blood carotenoids is expensive, invasive, and impractical, particularly in school-based settings. Skin carotenoid status assessed by resonance Raman spectroscopy (RRS) is a valid biomarker of FV intake ([10]) and has been used in school-based interventions. ([11,12]) However, RRS has limitations due to the lack of portability of the hand-built RRS machines, and the RRS devices that are portable are only available to researchers through a lease agreement wherein researchers pay a specific amount of money to use the RRS device for a specific amount of time, after which they must return the device to the company that owns the patent to the RRS device (Pharmanex).

Pressure-mediated reflection spectroscopy (RS) is an improved method (over RRS) to measure skin carotenoid status and is highly correlated with RRS-assessed skin carotenoids. ([13]) The Veggie Meter® is a portable RS device, and unlike the RRS device, it is available for purchase. The Veggie Meter® can be used easily in community-based settings. ([14,15]) The Veggie Meter® has been validated against plasma carotenoids in a small sample of racially diverse adults. ([16]) While RRS has been used in studies among 9–12 year old children to examine intervention effectiveness, ([11,12]) to our knowledge, no published studies have used the RS Device (the Veggie Meter®) in preschool and secondary school-based settings. Thus, the purpose of this study was to assess the associations between Veggie Meter®-assessed skin carotenoid status and self-reported FV intake in preschool and school-based settings.

METHODS

This was a cross-sectional study using data collected among preschool, middle school, and high school participants in eastern North Carolina (NC). Researchers had relationships with each setting based upon prior studies. ([17–19]) This study was approved by the East Carolina University Medical Center Institutional Review Board (UMCIRB 18–001535, UMCIRB 07–0741, and UMCIRB 18–002337).

Setting and Participants

Data collection for all three study populations occurred in Fall 2018, between October and December. Research staff went to each of the schools before the days of data collection to explain the Veggie Meter® device and study. For preschool students, the Veggie Meter® assessment occurred as part of an ongoing study, and participants had already provided parental consent. For middle and high school students, an informational sheet for students and parents, consent forms (for parents) and assent forms (for students) were provided in packets to take home. Students were told to read over the materials and if they wanted to participate in the study, they needed to bring the signed consent and assent forms back to school by the assigned date. Low-cost, age-appropriate incentives (stickers, ear buds, retail gift card) were provided for preschool, middle school, and high school participants, respectively.

Preschool participants were children recruited from three Head Start centers serving low-income families in one county. Middle school participants were recruited from 7th grade classes in three of 55 schools participating in an ongoing wellness intervention called the Motivating Adolescents with Technology to Choose Health (MATCH) program. ([18]) High school participants were recruited from a class that had previously participated in the “Go

Big and Bring it Home" project, which included text messages to encourage healthier eating patterns. ([19]) Demographics and dietary information were obtained via survey for all study participants.

Self-Reported Dietary Intake

Preschool participants completed the previously validated Pictorial Liking Tool ([20]) using an iPad. Use of the Pictorial Liking Tool is a valid form of self-reported FV liking among preschoolers, ([20]) and is preferred in this age group because parental recall of FV liking is thought to be unreliable in the preschool-based setting. ([21]) The tool featured 15 color photographs of a variety of foods, 12 of which were FV (i.e. red apple, broccoli, cucumber, cherry tomatoes, cauliflower, spinach, watermelon, carrots, sweet potatoes, radish, sweet peas, and green peppers). The tool used a 5-point hedonic liking scale ranging from "super yucky" to "super yummy." For analyses, a "1" was assigned to "super yucky" and a "5" was assigned to "super yummy". Responses were summed for all FV.

Middle school participants completed selected questions from the validated School Physical Activity and Nutrition (SPAN) questionnaire regarding frequency of their FV intake on the previous day, with questions about intake of orange vegetables, salad, starchy vegetables, fruit, fruit juice and soda, with additional questions about physical activity. ([22]) The options ranged from none to five or more times. Individual and summative scores from three vegetable questions (orange, salad, starchy), two fruit questions (fruit and fruit juice), and a soda question were used in analyses. Soda intake was selected as a variable of interest because we hypothesized that it would be a marker of a less healthy dietary pattern. ([23])

High school participants' FV intake was assessed by the National Cancer Institute (NCI) Fruit and Vegetable Screener. ([24]) The NCI screener measures the frequency and quantity of various FV consumed in the past month. The options for frequency range from never to five or more times per day, while the options for quantity vary by item. For example, the first item is: "Over the last month, how many times per month, week, or day did you drink 100% juice such as orange, apple, grape, or grapefruit juice? Do not count fruit drinks like Kool-Aid, lemonade, Hi-C, cranberry juice drink, Tang, and Twister. Include juice you drank at all mealtimes and between meals." Response options range from "Never" to "5 or more times per day." Participants were then asked, "Each time you drank 100% juice, how much did you usually drink?" with response options ranging from "less than ¾ cup (less than 6 ounces)" to "more than two cups". Two questions regarding soda and sweetened fruit drink (e.g., Kool-Aid) intake were also asked, adapted from the Behavioral Risk Factor Surveillance System questionnaire. As an example, the soda question was: "About how often do you drink regular soda or pop that contains sugar? Do not include diet soda or diet pop" with response options ranging from "never" to "5 or more times per day."

Skin Carotenoid Measurements

Skin carotenoids were assessed using the Veggie Meter®, which uses broad-band white light to measure skin carotenoids directly through their respective absorptions from 400–750 nm. Scores range from 0–800. Participants place their index finger on the bulb, a lever is lowered onto the finger, and a gentle pressure ensures an accurate reading. The Veggie Meter® is attached to a computer which shows the participant his/her reading immediately. The Veggie Meter® has been validated in a sample of racially diverse participants (n = 30) with a correlation between plasma carotenoids and Veggie-Meter®-assessed carotenoids of r = 0.71, p <0.0001). ([16])

Preschool participants were asked if they wanted "to play a game to see what color they get." The participant was then instructed to insert their right finger into the Veggie Meter® after wiping the finger with a sanitizing wipe. The multiple measurement mode was used which required children to insert and retract their finger into the machine three times. The Veggie Meter® took three measures during this time and produced an average score. Middle school and high school participants were called up individually to use the Veggie Meter®. Three consecutive measurements were taken on each participant, and the median measurement of the 3 scans was adopted as the Veggie Meter® reading for each participant. All participants completed dietary assessment measures immediately before or immediately after the Veggie Meter® reading.

Data Analyses

Univariate descriptive statistics were used to summarize the sample data. Spearman correlation coefficients were used to determine bivariate associations between measures of dietary intake and Veggie Meter®-assessed skin carotenoid levels. Analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC). The reliability of individual Veggie Meter readings was examined by intraclass correlation for middle school and high school students, and absolute differences among the three readings for middle and high school were examined using repeated measures ANOVA. We examined differences in Veggie Meter®-assessed skin carotenoid levels by gender, race, and weight category within each group using two-sample t-tests and analysis of variance.

RESULTS

Table 1 displays demographic characteristics of all three study samples. We found that preschool, middle, and high school participants were all willing to use the Veggie Meter®. Below we describe associations between dietary assessment and Veggie Meter® measures for each sub-population.

Preschool

Among the N= 112 participants, 43% were female, 81% were African American, and mean (SD) age was 4.1 (0.5) years. The mean (SD) Veggie Meter® Score was 266 (82.9). (Table 1). There were no statistically significant bivariate correlations between skin carotenoids and the liking scores for featured FV (Table 2).

Middle School

Among the N = 94 participants, sixty-one percent of middle school participants were female, 45% African American, and mean age was 12 years and 9 months. The mean (SD) Veggie Meter® score was 219 (SD 68.1). (Table 1) Veggie Meter® measurements were not significantly correlated with the self-reported SPAN FV intake or the summative scores of

FV intake (Table 2). The correlation between Veggie Meter® and soda intake was statistically significant with an inverse correlation of −0.2210 (p=0.0332), suggesting that as soda intake increased, skin carotenoids decreased.

High School

Among the N = 58 high schoolers, 65.5% were female, 50% were African American, 41% were Caucasian, and 25% were Hispanic, and mean age was 15 years and 3 months. The mean Veggie Meter® reading was 214 (SD 65.6). (Table 1) Veggie Meter® readings were not significantly associated with FV or soda/sweetened fruit drink intake. However, there was a marginally significant positive correlation with daily fruit intake (r = 0.2549, p =0.0557). (Table 2)

The intraclass correlation among the three readings was 0.857 for the middle school and 0.879 for the high school students, indicating high consistency. However, in terms of absolute difference, there were significant differences among the three readings for the middle school (p<0.001) and nearly significant differences for the high school (p=0.073), indicating relatively high variability among three readings.

Table 3 shows differences in Veggie Meter® scores by gender, race, and weight status. There was a statistically significant difference between males and females in the preschool group with males having mean Veggie Meter readings of 282.53 (75.14) and females having a mean of 243.44 (88.95), p = 0.0159. This was also true in the middle school group, with females having a mean of 204.38 (67.62) compared to males at 233.58 (60.95), p = 0.0515, with a similar non-statistically significant trend among high school students. No statistically significant differences were found across racial groups and weight categories.

DISCUSSION

This study determined that it is feasible to use the Veggie Meter® in preschool, middle, and high school-based settings. The Veggie Meter® was easy to set up and only required a small space, making it practical to use in school and community-based settings. Furthermore, the Veggie Meter® is objective and overcomes bias inherent in self-reported FV intake measures. ([6,7]) While previous studies have been conducted using the RRS in school- based settings, ([11,12]) our study is the first to report on use of the Veggie Meter® in three diverse pre-school and school-based populations. More studies are needed with children and adolescents in order to assess the validity (comparing with plasma-assessed carotenoids) and reproducibility of the Veggie Meter® in these populations.

The mean skin carotenoid status was higher in the preschool versus middle-and high-school students. Furthermore, the mean skin carotenoid status among males was higher than females in preschool, middle and high school students. It is unclear why this may be, but carotenoid status is influenced by several factors, including matrix of food, lipid consumed with the carotenoids, smoking status, age, and sex. ([25]) In the middle school population, soda intake was inversely correlated with skin carotenoids. This could be due to an overall poorer diet in the students who consumed more soda. ([23]) There was a positive association between skin carotenoids and fruit intake in high school students, which is what would be expected given several fruits contain carotenoids.

This study has several limitations. The sample size is small and conclusions should be interpreted with caution, especially from the stratified analyses. All participants were volunteers, so they may not be representative of the schools' populations. Assessment of FV intake was by self-report and may have been subject to bias. The Veggie Meter® is an assessment of skin carotenoids and thus does not detect all FV intake as some FV do not contain carotenoids. Finally, we did not examine validity of the Veggie Meter® by examining associations with plasma carotenoids. Such research in youth is needed to further determine Veggie Meter® validity.

CONCLUSIONS

The Veggie Meter® is an acceptable and feasible method to assess FV intake among youth. The tool is objective and overcomes bias inherent in self-reported FV intake measures. ([6,7]) The Veggie Meter® may also alleviate time and resource challenges related to collecting dietary intake data from children and adolescents in school and community-based settings. ([26]) The tool may be of particular interest to interventions focused on FV intake and/or working with younger children who are unable to complete traditional forms of dietary assessments (e.g. food recall) due to cognitive ability and limited reporting skills. ([27]) Similar to validation studies in adults, ([16,28]) in our study, skin carotenoid status was not associated with several validated self-report measures of FV intake among youth. Thus, to move the field forward, continued research is needed to determine associations with plasma carotenoids and Veggie Meter® assessed skin carotenoids in youth, including a thorough assessment of potential confounding variables that may affect skin carotenoid status in youth. Improved measurement of important dietary factors such as FV intake will enable researchers and practitioners to more efficiently evaluate nutrition interventions and policies, ultimately leading to dissemination of truly impactful interventions to promote healthy eating among youth.

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Table 1.

Participant Demographics in the Veggie Meter® Study from Preschool (n = 112), Middle School (n = 94), and High School (n = 58)

	Characteristics	Preschool N (%)	Middle School N (%)	High School N (%)
Sample Size	Students	112	94	58
	Schools/ Centers	3	3	1
Gender	Male	64 (57%)	31 (39%)	20 (34%)
	Female	48 (43%)	48 (61%)	38 (66%)
Race	Black	91 (81.3%)	35 (45%)	28 (50%)
	White	6 (5.4%)	18 (23%)	23 (41%)
	Other	15 (13.3%)	25 (32%)	5 (9%)
Weight Status	Overweight/Obese	48 (43%)	38 (52%)	24 (50%)
	Healthy weight	63 (57%)	35 (48%)	24 (50%)
		Mean (SD)	Mean (SD)	Mean (SD)
Age in years		4.1 (0.5)	12.8 (0.6)	15.3 (1.3)
BMI percentile		67.5 (32.1)	75.8 (26.4)	72.8 (26.4)
Skin Carotenoids by Veggie Meter®		266.0 (82.9)	219 (68.1)	214 (65.6)

Note: Due to missing data, the total number of available observations may be less than the total sample size at each school level for some variables.

Table 2.

Correlation between Veggie Meter® Readings and specified age-appropriate nutrition scales for the following student groups: preschool (N = 112)- fruit and vegetable (FV) liking scale; middle school (N = 94) - the School Physical Activity and Nutrition Survey (SPAN); and high school (N = 58)- National Cancer Institute (NCI) FV screener.

Dietary Component	Correlation coefficient (r-value)	P-Value
Correlation between Veggie Meter® and FV liking among N = 112 preschool students		
Apple	0.0379	0.6916
Broccoli	0.0047	0.9608
Cucumber	0.0190	0.8427
Black beans	−0.0173	0.8560
Cauliflower	−0.0279	0.7701
Spinach	−0.0665	0.4859
Watermelon	0.0154	0.8716
Carrots	0.0135	0.8877
Sweet Potato	−0.040	0.6763
Radish	−0.026	0.7852
Pea pods	0.0906	0.3423
Bell pepper	−0.1067	0.2630
Correlation between Veggie Meter® and SPAN FV and soda intake among N= 94 middle school students		
Orange Vegetables	0.0122	0.9080
Salad Vegetables	0.0487	0.6447
Other –non-starchy Vegetables	0.0123	0.9070
All (above 3 combined)	0.0560	0.5959
Starchy Vegetables	−0.0318	0.7623
Fruit	−0.1224	0.2452
Fruit+Juice	−0.0691	0.5151
Soda	−0.2210	0.0332
Correlation between Veggie Meter® and NCI FV screener and soda intake among high school students (N = 58)		
Juice	0.1674	0.2175
Fruit	0.2549	0.0557
Salad	0.1321	0.3319
Fries	−0.0964	0.4799
Potato	0.0141	0.9195
Beans	0.0779	0.5649
Other Vegetables	0.0864	0.5507
Tomato	0.1672	0.2139
Vegetable soup	−0.0117	0.9366
Soda	−0.0064	0.9625
Sweetened fruit drinks	0.1861	0.1657

Table 3.

Veggie Meter®-assessed skin carotenoid levels stratified by Gender, Race, and Weight Category among (N = 112) preschool students; middle school students (N = 94); high school students (N = 58).

Characteristic	Mean Veggie Meter®-Assessed Skin Carotenoid Level	Standard Deviation	P-value for difference
Preschool Students			
Gender			
Female	243.44	88.95	0.0159
Male	282.53	75.14	
Race			
Black	265.23	84.39	0.8970
White	281.00	91.55	
Other	263.00	77.93	
Weight Category			
Healthy Weight	260.40	89.11	0.3643
Overweight or obese	274.60	75.00	
Middle School Students			
Gender			
Female	204.38	67.62	0.0515
Male	233.58	60.95	
Race			
Black	231.09	52.42	0.1964
White	198.82	63.71	
Other	208.28	82.39	
Weight Category			
Healthy Weight	219.26	70.66	0.6969
Overweight or obese	213.11	62.16	
High School Students			
Gender			
Female	205.63	72.95	0.0645
Male	236.58	49.30	
Race			
Black	234.33	76.23	0.0727
White	191.57	48.60	
Other	225.14	66.26	
Weight Category			0.7781
Healthy Weight	221.43	76.85	
Overweight or obese	215.75	58.97	