2018

Systematic analysis of food visual estimation methods and applications in school lunch

Yuanying Lou
Iowa State University

Systematic analysis of food visual estimation methods and applications in school lunch

by

Yuanying Lou

A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Nutritional Sciences

Program of Study Committee:
Lorraine Lanningham-Foster, Major Professor
Ruth Litchfield
Greg Welk
Spyridoula Vazou
Huaiqing Wu

The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this dissertation. The Graduate College will ensure this dissertation is globally accessible and will not permit alterations after a degree is conferred

Iowa State University

Ames, Iowa

2018

DEDICATION

Dedicated to my Lord and Savior, Jesus Christ

The fear of the Lord is the beginning of wisdom: and the knowledge of the holy is understanding.

Proverbs 9:10

For in him dwelleth all the fullness of the Godhead bodily.

And ye are complete in him, which is the head of all principality and power.

Colossians 2:9-10

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

NOMENCLATURE

AND	Academy of Nutrition and Dietetics
BMI	Body Mass Index
DRI	Dietary Reference Intakes
CDC	Center of Disease Control and Prevention
FNS	Food and Nutrition Services
HHFKA	Healthy Hunger-Free Kids Act
ICC	Intra-class Correlation
IOM	Institute of Medicine
NSLP	National School Lunch Program
RDA	Recommended Dietary Allowances
RMSE	Root Mean Square Error
SMI	School Meals Initiative for Healthy Children
SNDA	School Nutrition Dietary Assessment
SY	School Year
USDA	United States Department of Agriculture
US	United States

ACKNOWLEDGEMENTS

First and foremost, my thanks and praise go to my LORD Jesus Christ! He is my strength and my shield; my heart trusts in Him and leaps for joy. I feel very grateful that no matter what challenges might be, He is always with me to provide the strength, wisdom, endurance, and hope inside of me. His word is a lamp for my feet and a light on my path to direct my way during the course of this research.

I would like to sincerely thank my major professor, Dr. Lanningham-Foster, for her warm encouragement, intellectual guidance, enthusiasm, and unwavering support throughout the course of my doctoral program and research. She is my mentor not only from the aspect of professional, but also of personal, who taught me a lot on how to balance work and life. I am very grateful to spend four years in her laboratory interacting with many excellent graduate and undergraduate students. And thanks for the valuable opportunities she provided to me to involve in multiple research projects and gain precious experience during the process.

My sincere gratitude also goes to my committee members, Dr. Litchfield, Dr. Welk, Dr. Vazou, and Dr. Wu. I appreciated a lot for their time and expertise they shared with me during the course of my research, as well as their encouragements and advice which enhance my study a lot at Iowa State University. I would also like to acknowledge Dr. Wu for his patience and help on the statistical analysis in my research studies.

A special thank you to the undergraduate students in Dr. Lanningham-Foster's lab who helped me during the process of data collection, processing, and analysis. This process became easier and fun with your help and support. I also would like to thank the food service personnel in Ankney school district who helped me during the plate waste studies. And thanks to all the students for their collaborations in the process of data collection. I am very grateful to have such

wonderful fellow graduate students and the department faculty and staff. Without you, my journey at Iowa State University would not be such great and memorable!

Last but not least, I would like to extend my gratitude to the sisters and brothers in my church, Ames Chinese Christian Assembly. Your prayers and love in God always motive me to move forward boldly! Sincerely thank you, my parents and family for your unconditional trust and support as well as providing me a sweet home forever. A special thanks to my husband, Hao. I am so blessed to have you in my life that we could together know God and experience the new man in Jesus Christ.

ABSTRACT

Valid and reliable dietary assessment methods play a vital role in understanding children's dietary behaviors and intake. Photo-based visual estimation methods with high flexibility, cost-effectiveness, and lower burden have been developed rapidly and applied widely recently. To promote its further application, it is necessary to perform a systematic analysis to investigate various commonly used visual estimation systems in the context of considering various influencing factors. A photo-based online survey was developed in the first study to evaluate the accuracy of four visual estimation systems: Third, Quarter, Eighth, and Continuous. Participants' information including sex, age, height and weight, and major background characteristics was collected to explore the effects of these factors on visual estimation accuracy. Overall, the Quarter and Eighth systems had higher accuracy than the Third and Continuous systems. The system accuracy may also be affected by personal- and food-related factors in different ways among the four systems. Additionally, a majority of the survey population (59%) preferred to use the Quarter system for food visual estimations. Therefore, Quarter system was applied to evaluate the effects of SWITCH programming on improving students' fruit and vegetable consumption (study 2), as well as energy and nutrient intake (study 3). Students in the 5th grade participating in the National School Lunch Program from four elementary schools were involved in both studies. Two schools participated in SWITCH and two did not. Results of the second study demonstrated that students participating in SWITCH significantly increased fruit consumption from 0.37 cups at baseline to 0.50 cups at endpoint. The increase in fruit consumption might potentially enhance students' nutrient intake during lunch, which was supported by the third study. Students participating in SWITCH significantly increased their fiber selection and decreased their sodium selection and intake. The percentage of students meeting

2010 IOM recommendations for energy and fiber were also increased in SWITCH schools. Findings from this dissertation provide valuable guidance on selecting proper visual estimation systems as well as support the SWITCH program as a promising school wellness initiative to enhance children's healthy eating and nutrition status.

CHAPTER 1. INTRODUCTION

Background Introduction

As defined by the World Health Organization (WHO), obesity is a medical condition in which excessive or abnormal body fat accumulates to an extent that will exert negative effects on health.[1] In 2013, the American Medical Association (AMA) officially recognized obesity as a chronic disease state.[2]

As a good indicator of body fatness, which closely correlates with some health consequences such as cardiovascular diseases, diabetes, cancers, *etc*., Body Mass Index (BMI) is the most commonly used measurement to classify weight status in adults. However, it would not be appropriate to apply the BMI categories (i.e. cut-off points) used in adults to define the weight status in children and adolescents. Because body composition changes quickly during childhood, and growth is different between boys and girls, BMI is specific to gender and age in youth. Hence, the age- and gender-specific percentiles for BMI are adopted by the U.S. Centers for Disease Control and Prevention (CDC) to determine a child or adolescent's weight status.[3] Table 1.1 compares such criteria used in children and adult populations. Beside BMI, there are a number of other ways to measure body fatness, such as dual energy X- ray absorptiometry, bioelectrical impedance analysis, densitometry, and isotope dilution method.[4] In addition, waist circumference is widely used to assess abdominal fat, however, the cut-off points used in the adult population cannot simply be related to health status in children and adolescents.[5]

Table 1.1. Determining the weight status in adults or children and adolescents [a].

Weight status category	BMI range used in adults (kg/m^2)	BMI percentile used in children and adolescents [b]
Underweight	<18.5	<5th percentile
Normal weight	18.5-24.9	5th to less than 85th percentile
Overweight	25-29.9	85th to less than 95th percentile
Obesity	≥ 30	95th percentile and above
Extreme obesity	≥ 40	99th percentile and above

Note: [a] Adults are defined as people above 19 years old. Children and adolescents are defined as being aged 2 to 19 years. [b] BMI is assessed by age- and sex-specific percentiles based on CDC growth chart.[6]

Childhood obesity has become one of the most challenging problems in the United States, threatening millions of children and adolescents' health. It was estimated more than 1 in 3 children in U.S were determined to have either overweight or obesity.[7] According to the most recent data from the National Health and Nutrition Examination Survey (NHANES) in the year of 2015-2016, the prevalence of obesity in U.S youth aged 2-19 years was 18.5%, affecting about 13.7 million children and adolescents.[8] The data indicated the school-aged children (i.e. 6-11 years old) and adolescents (i.e.12-19 years old) had a higher prevalence of obesity (18.4 % and 20.6%, respectively), compared to preschool-aged children (i.e. 2-5 years old, 13.9%).[8] During the past 30 years, childhood obesity rates have more than doubled in school-aged children, and more than quadrupled in adolescents.[7] The obesity rate in children and adolescents varied by race and socio-economic status: the obesity prevalence was higher in Hispanic (25.8%) and non-Hispanic-black(22%) comparing to non-Hispanic white (14.1%) and non-Hispanic Asian (11%) [8]; as the level of education of the household increased, the childhood obesity prevalence decreased.[9]

Children and adolescents with overweight or obesity are at higher risk of suffering a wide range of health complications. Several studies demonstrated the social isolation and psychological dysfunctions experienced by children with obesity, even starting from an early age. [10,11] Hill and Silver (1995) found a clear association between body dissatisfaction and the state of overweight or obesity, in particular in females.[12]

In addition, children and adolescents with overweight and obesity may experience many health problems affecting lots of organs and systems, including respiratory, orthopedic, gastrointestinal, cardiovascular, endocrine, neurological, and reproductive systems.[13,14]

In the long term, children with obesity have a higher likelihood to become adults with obesity.[15] Whitaker et al. (1997) demonstrated that being overweight for more than 6 years during childhood might increase the risk of having obesity in adulthood.[16] Must et al. (1992) indicated that regardless the weight status in adults, the weight status of overweight in childhood was a predictor of cardiovascular-related morbidity and mortality in adulthood.[17] Furthermore, females with overweight or obesity in late adolescence or early adulthood were associated with a higher poverty rate, lower marriage rate, and lower family income.[10]

The accumulation of excessive body fat results from a long-term positive energy balance in which energy intake exceeds energy expenditure.[18] The process of obesity development is quite complex with the interactions among different factors, including not only genetic traits, but developmental, environmental, and behavioral factors as well.[19]

The application of genome-wide association studies (GWAS) in the last two decades largely contributed to the identification of gene variants which increase the risk of developing obesity.[20] Epigenetic modifications and some specific biochemical and physiological mechanisms were found to be associated with energy imbalance, leading to the development of obesity.[20]

The expression of certain genes might make some individuals predisposed to become obese, however, genetic factors are not the only explanation to the current worldwide obesity epidemic. Hill and Peter (1998) pointed out that the increasing obesity prevalence was largely related to an "obesogenic environment", in which excessive food intake is promoted while physical activity is discouraged.[18] It is important to note that environmental influence must be mediated through related dietary and physical activity behaviors.[21] In other words, the behaviors act as a bridge to link the human biology with the environment to which the population is exposed. The current environment provides children with more frequent opportunities to consume food with a larger portion size, especially foods high in fat or high in refined-grains.[22] As with the popularization of automobiles, a sedentary life style is being promoted.[19,23] An inverse relationship between physical activity level and adiposity level was reported in a previous study from Sunnegardh et al.(1986).[24] In addition to diet and physical activity, socio-economic status might also be associated with the development of childhood obesity. As mentioned Booth et al. (1999), a strong inverse relationship was found between obesity rates and socio-economic status.[25] Analyzing the factors in depth, it was found that parental education and occupation were inversely related to children's obesity rate, while a neglectful home environment was positively associated with obesity rates in children.[19]

The pediatric obesity epidemic has resulted in serious health complications and heavy economic burden. Although genetic traits may increase some individual's vulnerability to acquire obesity, environmental and behavioral factors should be given more attention. Therefore, behavioral-focused interventions to improve the diet and physical activity behaviors and to promote positive environmental changes are in high demand to reverse the pediatric obesity epidemic.

Childhood obesity prevention and treatment programs could be delivered in various settings at multiple levels. The most common settings include family, school, primary care office, and community. Compared to other settings, schools offer additional advantages in conducting pediatric overweight and obesity prevention programs, especially at the primary level. Schools also provide physical and social environments that have a significant influence on students' behaviors and overall health .[19,26,27] Hence, schools have become a key target in many childhood obesity prevention programs. Multiple components focusing on diet, physical activity, sedentary behaviors, and parents/family involvement are commonly included in the school-based childhood obesity prevention interventions. As concluded in a review from Kriemler et al. (2011), evidence from previous research suggests that multicomponent school-based interventions may be the most promising and consistent strategy to enhance fitness and improve physical activity in youth.[28]

SWITCH is a multicomponent childhood obesity prevention program, which focuses on helping children to increase their physical activity, decrease screen time, and increase fruit and vegetable consumption. Three education modules, i.e. the Classroom module, Lunchroom module, and PE module, were created and implemented in participating schools to better facilitate the schools' coordinating roles and promote environmental and behavioral changes. The SWITCH Lunchroom module focuses on modifying the school cafeteria environment by providing resources, activities, and strategies (such as plate waste studies, and fruit and vegetable tastings). Among all environments in school that the students are exposed to, the cafeteria is an important one with a direct influence on students' eating behaviors. In particular, the quality of school meals can significantly affect dietary intake and overall health in children. Gleason and Suitor (2001) indicated the dietary patterns and mean intakes of many nutrients were better in students participating in the National School Lunch Program (NSLP) than non-participants.[29] Policies and regulations were developed requiring the school meals meet certain nutritional goals to improve the meal quality and enhance students' dietary intakes. Multiple reports from the ongoing School Nutrition Dietary Assessment (SNDA) study have shown that schools have made considerable improvements in meal quality after implementing such policies and regulations.[30–33] However, based on the most recent report from this study, only 7% of the school lunches selected by students met all the nutritional goals.[33] Meeting the recommendations on fruit and vegetable intake is particularly challenging. For example, the quantity of vegetables offered at school lunch is recommended to be 3.75 cups per 5-day week, equal to 0.75 cups per day.[34] However, two studies estimated the vegetable consumption to be 0.31-0.35 cups per day, much lower than the recommendation.[35,36] Evidence from previous studies showed the environmental changes in the school cafeteria could promote students' healthy eating, especially increasing fruit and vegetable selection and consumption.[37–40]

Valid dietary assessment methods play a key role in evaluating the effects of such programs or practices on improving children's dietary behaviors and nutrient intakes. Self-reported dietary assessments are widely used in the adult population to obtain dietary information. However, children's limitations on food knowledge, memory, literacy, and attention hinder the applications of self-reported dietary assessment methods,[41] especially in the context of overweight and obesity.[42] The weighing method is objective and accurate in providing the dietary intake information, and has been used in many school plate waste studies.[43] However, it is time-consuming, burdensome, and potentially may interrupt the normal school lunch pattern.

Visual estimation methods provide researchers alternatives when assessing children's dietary intake. Compared to on-site visual estimations, the photo-based visual estimation method is more flexible, cost-effective, and easy to implement.[44] Photo-based diet assessment has been shown to be a valid and reliable method in measuring dietary intake by comparing to a gold standard method (such as direct weighing or Doubly Labeled Water method).[45,46] After systematically reviewing the plate waste studies conducted in schools, it was found that the photo-based visual estimation method was used more frequently in the recent 10 years, helping identify the patterns of food selection, waste, and consumption, or evaluating the effects of some intervention programs on students' dietary behaviors.[43]

However, some research gaps and limitations have been identified in applying photo-based visual estimations. Various rating scales have been used in previous studies to estimate the food waste/selection, however, few studies compared their accuracies in the same setting. In addition, various personal-related, food-related, and psychological factors could influence the accuracy of visual estimation. To provide a better guidance on selecting a proper rating scale used in photo-based visual estimations for a specific setting or population, studies comparing the accuracies of different rating scales and exploring the influence of various affecting factors are needed.

Dissertation Organization

The chapters presented in this dissertation are intended to address the research needs in food visual estimations and to apply these findings in school-based childhood obesity prevention programs. An introduction, a general review of literature, three manuscripts, and an overall summary and conclusion are included. The comprehensive literature review is presented in Chapter 2, discussing the school-based childhood obesity interventions, the influence of school cafeterias on students' dietary behaviors and nutrient intake, and the development and application of food visual estimation methods. A photo-based visual estimation online survey is presented in the study in Chapter 3 to compare the accuracies of four visual estimation rating scales and explore the influence of some personal- and food-related factors on specific rating scales. Based on the results from Chapter 3, an appropriate rating scale used in visual estimations was selected to detect the effects of SWITCH programming on the dietary patterns of school lunches, especially focusing on fruit and vegetable selection and consumption (focus of Chapter 4). The influence of SWITCH on energy and nutrient intake are further discussed in Chapter 5, which also identified the factors influencing whether schools were meeting nutritional recommendations. Figure 1.1 summarizes the relationship among the three main studies (Chapter 3, 4, and 5), and also identifies the research questions needed to be addressed in each study. An overall summary of the results as well as a preview for future research are discussed in Chapter 6. All supporting materials and documents (including the approvals from the Institutional Review Board of Iowa State University) are included in referenced Appendices.

Figures

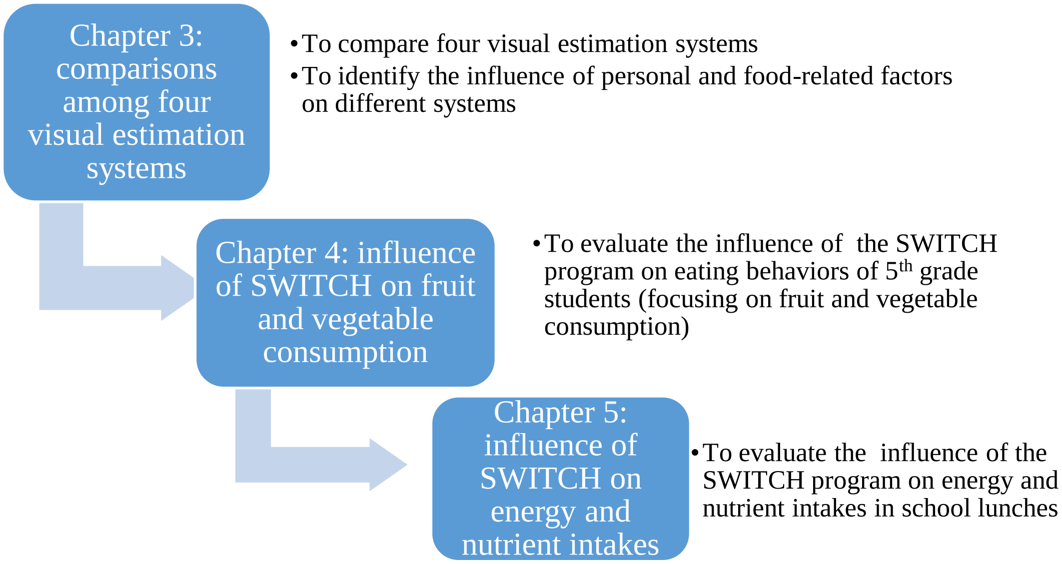


Figure 1.1 Overall organization of the three studies and their objectives**.**

References

1. World Health Organization. Obesity. WHO. http://www.who.int/topics/obesity/en/. Published 2014. Accessed August 13, 2018.

2. American Medical Association. *Report of the Council on Science and Public Health - Report 3-A-13*.; 2013. https://www.ama-assn.org/sites/default/files/media-browser/public/about-ama/councils/Council Reports/council-on-science-public-health/a13csaph3.pdf. Accessed August 13, 2018.

3. Chinn S. Definitions of childhood obesity: current practice. *Eur J Clin Nutr*. 2006;60(10):1189-1194. doi:10.1038/sj.ejcn.1602436.

4. Wells JCK, Fewtrell MS. Measuring body composition. *Arch Dis Child*. 2006;91(7):612-617. doi:10.1136/adc.2005.085522.

5. Rudolf MCJ, Greenwood DC, Cole TJ, et al. Rising obesity and expanding waistlines in schoolchildren: a cohort study. *Arch Dis Child*. 2004;89(3):235-237. http://www.ncbi.nlm.nih.gov/pubmed/14977700. Accessed August 13, 2018.

6. Statistics H, Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Roche AF. *Advance Data from Vital and Health Statistics, No. 314 (12/04/00)*. Vol 314.; 2000. http://www.cdc.gov/growthcharts. Accessed August 13, 2018.

7. Fryar CD, Carroll MD, Ogden CL. Prevalence of Overweight and Obesity Among Children and Adolescents: United States, 1963–1965 Through 2011–2012. *Natl Heal Nutr Exam Surv*. 2012. https://www.cdc.gov/nchs/data/hestat/obesity_child_11_12/obesity_child_11_12.pdf. Accessed March 20, 2018.

8. Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of Obesity Among Adults and Youth: United States, 2015–2016 Key findings Data from the National Health and Nutrition Examination Survey. *NCHS Data Brief*. 2017;(288):1-8. https://www.cdc.gov/nchs/data/databriefs/db288.pdf. Accessed March 20, 2018.

9. Ogden CL, Carroll MD, Fakhouri TH, et al. Prevalence of Obesity Among Youths by Household Income and Education Level of Head of Household — United States 2011–2014. *MMWR Morb Mortal Wkly Rep*. 2018;67(6):186-189. doi:10.15585/mmwr.mm6706a3.

10. Gortmaker SL, Must A, Perrin JM, Sobol AM, Dietz WH. Social and Economic Consequences of Overweight in Adolescence and Young Adulthood. *N Engl J Med*. 1993;329(14):1008-1012. doi:10.1056/NEJM199309303291406.

11. Must A, Strauss R. Risks and consequences of childhood and adolescent obesity. *Int J Obes*. 1999;23(S2):S2-S11. doi:10.1038/sj.ijo.0800852.

12. Hill AJ, Silver EK. Fat, friendless and unhealthy: 9-year old children's perception of body shape stereotypes. *Int J Obes Relat Metab Disord*. 1995;19(6):423-430. http://www.ncbi.nlm.nih.gov/pubmed/7550528. Accessed August 14, 2018.

13. Deckelbaum RJ, Williams CL. Childhood Obesity: The Health Issue. *Obes Res*. 2001;9(S11):239S-243S. doi:10.1038/oby.2001.125.

14. Goran MI, Gower BA. Relation between visceral fat and disease risk in children and adolescents. *Am J Clin Nutr*. 1999;70(1):149S-156S. doi:10.1093/ajcn/70.1.149s.

15. Berkey CS, Rockett HR, Field AE, et al. Activity, dietary intake, and weight changes in a longitudinal study of preadolescent and adolescent boys and girls. *Pediatrics*. 2000;105(4):E56. doi:10.1542/PEDS.105.4.E56.

16. Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH. Predicting Obesity in Young Adulthood from Childhood and Parental Obesity. *N Engl J Med*. 1997;337(13):869-873. doi:10.1056/NEJM199709253371301.

17. Must A, Jacques PF, Dallal GE, Bajema CJ, Dietz WH. Long-Term Morbidity and Mortality of Overweight Adolescents. *N Engl J Med*. 1992;327(19):1350-1355. doi:10.1056/NEJM199211053271904.

18. Hill JO, Peters JC. Environmental contributions to the obesity epidemic. *Science*. 1998;280(5368):1371-1374. http://www.ncbi.nlm.nih.gov/pubmed/9603719. Accessed August 14, 2018.

19. Hills AP, King NA, Byrne NM. *Children, Obesity and Exercise : Prevention, Treatment, and Management of Childhood and Adolescent Obesity*. Routledge; 2007. https://www.routledge.com/Children-Obesity-and-Exercise-Prevention-Treatment-and-Management-of/Hills-King-Byrne-Bailey-ICSSPE/p/book/9780415408844. Accessed August 14, 2018.

20. Schwartz MW, Seeley RJ, Zeltser LM, et al. Obesity Pathogenesis: An Endocrine Society Scientific Statement. *Endocr Rev*. 2017;(June):1-30. doi:10.1210/er.2017-00111.

21. Crawford D, Ball K. Behavioural determinants of the obesity epidemic. *Asia Pac J Clin Nutr*. 2002;11(s8):S718-S721. doi:10.1046/j.1440-6047.11.s8.14.x.

22. Popkin BM. The Nutrition Transition and Obesity in the Developing World. *J Nutr*. 2001;131(3):871S-873S. doi:10.1093/jn/131.3.871S.

23. Lanningham-Foster L, Nysse LJ, Levine JA. Labor Saved, Calories Lost: The Energetic Impact of Domestic Labor-saving Devices. *Obes Res*. 2003;11(10):1178-1181. doi:10.1038/oby.2003.162.

24. SUNNEGARDH J, BRATTEBY L-E, HAGMAN U, SAMUELSON G, SJOLIN S. Physical Activity in Relation to Energy Intake and Body Fat in 8- and 13-Year-Old Children in Sweden. *Acta Paediatr*. 1986;75(6):955-963. doi:10.1111/j.1651-2227.1986.tb10323.x.

25. Booth M, Macaskill P, Lazarus R, Baur L. Sociodemographic distribution of measures of body fatness among children and adolescents in New South Wales, Australia. *Int J Obes*. 1999;23(5):456-462. doi:10.1038/sj.ijo.0800841.

26. Hoelscher DM, Kirk S, Ritchie L, Cunningham-Sabo L. Position of the Academy of Nutrition and Dietetics: Interventions for the Prevention and Treatment of Pediatric Overweight and Obesity. *J Acad Nutr Diet*. 2013;113(10):1375-1394. doi:10.1016/j.jand.2013.08.004.

27. Association AD, (ADA). Position of the American Dietetic Association: individual-, family-, school-, and community-based interventions for pediatric overweight. *J Am Diet Assoc*. 2006;106(6):925-945. doi:10.1016/j.jada.2006.03.001.

28. Kriemler S, Meyer U, Martin E, van Sluijs EMF, Andersen LB, Martin BW. Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of reviews and systematic update. *Br J Sports Med*. 2011;45(11):923-930. doi:10.1136/bjsports-2011-090186.

29. Gleason P, Suitor C. Children's Diets in the Mid-1990s: Dietary Intake and Its Relationship with School Meal Participation. *Math Policy Res Reports*. https://ideas.repec.org/p/mpr/mprres/8db693ba4d8640ec87d978a342a6ec5d.html. Accessed August 8, 2018.

30. Burghardt JA, Devaney BL, Gordon AR. The School Nutrition Dietary Assessment Study: summary and discussion. *Am J Clin Nutr*. 1995;61(1):252S-257S. doi:10.1093/ajcn/61.1.252S.

31. Fox MK, Crepinsek MK, Connor P, Battaglia M. *School Nutrition Dietary Assessment Study-II Final Report*.; 2001. http://www.fns.usda.gov/oane. Accessed September 2, 2018.

32. Gordon A, Crepinsek MK, Nogales R, Condon E. School Nutrition Dietary Assessment Study III, Volume I: School Food Service, School Food Environment, and Meals Offered and Served. *Math Policy Res Reports*. https://ideas.repec.org/p/mpr/mprres/2429f1634e2d4dcca2e68d5f71078b60.html. Accessed February 15, 2018.

33. Fox MK, Condon E. *School Nutrition Dietary Assessment Study-IV Summary of Findings*.; 2012. www.fns.usda.gov/cnd. Accessed August 5, 2018.

34. Stallings VA, Suitor CW, Taylor CL. *School Meals*.; 2010. doi:10.17226/12751.

35. Cohen JFW, Richardson S, Parker E, Catalano PJ, Rimm EB. Impact of the new U.S. Department of Agriculture school meal standards on food selection, consumption, and waste. *Am J Prev Med*. 2014;46(4):388-394. doi:10.1016/j.amepre.2013.11.013.

36. Cullen KW, Chen T-A, Dave JM. Changes in foods selected and consumed after implementation of the new National School Lunch Program meal patterns in southeast Texas. *Prev Med reports*. 2015;2:440-443. doi:10.1016/j.pmedr.2015.05.007
.

37. Perry CL, Bishop DB, Taylor GL, et al. A Randomized School Trial of Environmental Strategies to Encourage Fruit and Vegetable Consumption among Children. *Heal Educ Behav*. 2004;31(1):65-76. doi:10.1177/1090198103255530.

38. Cullen KW, Chen T-A, Dave JM, Jensen H. Differential Improvements in Student Fruit and Vegetable Selection and Consumption in Response to the New National School Lunch Program Regulations: A Pilot Study. *J Acad Nutr Diet*. 2015;115:743-750. doi:10.1016/j.jand.2014.10.021.

39. Swanson M, Branscum A, Nakayima PJ. *Promoting Consumption of Fruit in Elementary School Cafeterias. The Effects of Slicing Apples and Oranges*. Vol 53.; 2009. doi:10.1016/j.appet.2009.07.015.

40. Schwartz MB. The influence of a verbal prompt on school lunch fruit consumption: a pilot study. *Int J Behav Nutr Phys Act*. doi:10.1186/1479.

41. Livingstone MBE, Robson PJ. Measurement of dietary intake in children. *Proc Nutr Soc*. 2000;59(2):279-293. doi:10.1017/S0029665100000318.

42. Collins CE, Watson J, Burrows T. Measuring dietary intake in children and adolescents in the context of overweight and obesity. *Int J Obes*. 2010;34(7):1103-1115. doi:10.1038/ijo.2009.241.

43. Byker Shanks C, Banna J, Serrano EL. Food Waste in the National School Lunch Program 1978-2015: A Systematic Review. *J Acad Nutr Diet*. 2017;117(11):1792-1807. doi:10.1016/j.jand.2017.06.008.

44. Martin CK, Nicklas T, Gunturk B, Correa JB, Allen HR, Champagne C. Measuring food intake with digital photography. *J Hum Nutr Diet*. 2014;27(s1):72-81. doi:10.1111/jhn.12014.

45. Williamson DA, Allen HR, Martin PD, Alfonso AJ, Gerald B, Hunt A. Comparison of digital photography to weighed and visual estimation of portion sizes. *J Am Diet Assoc*. 2003;103(9):1139-1145. doi:10.1016/S0002-8223(03)00974-X.

46. Nicklas T, Saab R, Islam NG, et al. Validity of the Remote Food Photography Method Against Doubly Labeled Water Among Minority Preschoolers. *Obesity*. 2017;25(9):1633-1638. doi:10.1002/oby.21931.

CHAPTER 2. LITERATURE REVIEW

Part I: School-based Childhood Obesity Prevention Programs

Various Settings for Childhood Obesity Prevention Programs

According to the position papers related to the prevention and treatment of childhood overweight and obesity published by the Academy of Nutrition and Dietetics (AND) in 2006 and 2013, childhood obesity prevention interventions were designed based on comprehensive models involving various components in multiple settings at different levels.[1,2] The systematic evaluations and evidence-based analysis of the literature indicated that the pediatric overweight and obesity interventions were commonly delivered in individual-, family-, school-, and community-based settings.[1]

There was sufficient evidence to recommend that the multicomponent family-based interventions be conducted among school-aged children, and fair evidence for these interventions to be conducted in adolescents.[1] Parents are very important role models and have a strong influence on their children's dietary and physical activity behaviors; therefore, parent involvement is a very important component for delivering a successful childhood obesity program, regardless of the settings in which the interventions were implemented.[3,4]

Community-based interventions could reach a larger portion of the population and influence people's behaviors through providing the related physical and social environments. As a result, these types of interventions became attractive in pediatric obesity prevention and treatment.[5–7] Although previous research provided some evidence to support their feasibility and potential influence on eating and physical activity behaviors, there was still no strong evidence to show the relationship between the community-based interventions and the weight status in youth.[1]

School provides an ideal setting for delivering childhood overweight and obesity intervention programs. Previous research indicated the need to promote multicomponent school-based interventions. As indicated in the AND position paper (2013), school-based interventions not only have a positive influence on improving the adiposity measurements, but also improve some obesity-related behaviors, such as increasing fruit and vegetable consumption, increasing physical activity time, and decreasing screen time.[2]

Roles of School Environment in Childhood Obesity Prevention

School-aged children and adolescents spend more than 1,200 hours per year in school, which places schools at an important position in influencing children's dietary and physical activity behaviors. Compared to other settings in which childhood obesity prevention programs were conducted, schools offer many advantages: reaching a large number of students at one time; involving and engaging parents conveniently; conducting health and wellness policies and regulations in a consistent way; and being cost-effective.[3,8]

Schools provide significant physical environments such as the school cafeteria, gym, and playground as well as social environments such as the interactions between students and teachers, and between students and students. Promoting healthy life-style behaviors should not be limited only to the health teaching in schools, but should be implemented throughout the whole school environment.[8] Physical activity level can be increased through physical education curriculum, as well as through activities throughout the school day, including active transportation to and from schools, activity breaks, after school programs, recess, and sports.[9] The school cafeteria and school meals are good opportunities to promote healthy eating choices and improve dietary behaviors in youth. A number of studies provided evidence showing the modifications in the school cafeteria could lead to positive changes in dietary behaviors, such as increasing fruit and vegetable consumption.[10–13] Providing training to teachers was also necessary to foster their knowledge and understanding of some key concepts related to eating and physical activity, and to equip educators with effective strategies for behavioral change.[3] Regardless of the weight status, children's behaviors were strongly influenced by the environments in which they lived.[2,3]

Polices and regulations could provide environmental support to promote and maintain the behavioral changes.[14] In 2016, the United States Department of Agriculture (USDA) finalized the regulations for Local School Wellness Policy implementation under the Health, Hunger-Free Kids Act of 2010 (2010 HHFKA). Schools were required to promote students' health and wellness through setting specific goals for nutrition and physical activities, meeting related nutrition standards for all foods and beverages provided in national school meal programs or sold to students on campus, implementing evidence-based strategies, and establishing wellness policy leadership.[15] In addition, the general public and school community (including parents, students, school administrators, school health professionals, teachers of physical activity, and school food authorities) should be allowed to participate in the school wellness policy process.[15]

Multiple Components Involved in School-based Interventions

A multicomponent school-based childhood obesity intervention is defined as an intervention including at minimum the nutrition education and physical activity component.[1] A review paper from Kriemler et al. (2011) analyzing the effects of school-based interventions concluded that the multicomponent school-based intervention was found to be the most consistent and promising strategy to promote physical activity and fitness in children and adolescents.[8] After evaluating and analyzing twenty-three multicomponent school-based primary preventions and five systematic reviews (including one meta-analysis), the AND made a similar conclusion that fair evidence (Grade II) was found to support the effects of multicomponent school-based interventions on improving adiposity measures and obesity-related behaviors.[1,2] In addition to nutrition education and physical activity, parent/family involvement and modifications of sedentary behaviors are the components that are commonly included.

Dietary component

Nutrition plays a very important role in influencing children's development and growth.[16] Unhealthy eating patterns are associated with adverse serum lipoprotein profiles, insulin resistance, hypertension, and an increased risk for developing chronic diseases.[3] In the context of the pediatric obesity epidemic, improving dietary behaviors has become particularly important. Considering children are experiencing rapid development of their bodies, sufficient and balanced nutrition is necessary to maximize their growth and improve their health. Therefore, the focus of nutrition intervention should be on promoting healthy eating, rather than weight-loss.[17] Furthermore, the variety of food that the students could select should be emphasized, instead of food being restricted.[3]

Nutrition education is one of the most common strategies used in nutrition interventions. General information and knowledge regarding food composition, food labels, and the components of healthy meals will be provided to students through teaching or related education materials. The nutrition education in most school-based interventions are behaviorally based, and the Social Cognitive Theory is the most commonly used model.[1] Based on the studies conducted so far, AND cannot find sufficient evidence to support the effectiveness of the nutrition education alone to improve adiposity measures or promote healthy dietary behaviors.[1,2] However, research has provided consistent evidence to show the influence of nutrition education as part of a multicomponent school-based intervention on changing students' dietary behaviors or weight status.[1,2]

The food environment (including physical, social, and person-centered environments) has become a significant target in childhood obesity interventions due to its impact on children's dietary patterns. In school-based pediatric obesity interventions, the changes in the food environment usually involve modifications that occur in the school cafeteria, such as improving food service practices, implementing certain rules/regulations to enhance nutrition quality of school meals, and increasing students' accessibility and availability to more healthy food during a school day. Research studies have demonstrated the positive effects of food environment changes on improving the students' dietary behaviors and nutrition intake. [12,18–20] More details will be discussed further in the later section of this chapter: *Part II Influence of School Cafeteria on Students' Dietary Behaviors and Intakes*.

Packed lunches brought from home is another important aspect that needs improvements. It was estimated that on an average day in the school year 2009-2010, about 40% of all public school students in the U.S. brought lunch from home.[21] Johnston *et al.* indicated in the article (2012) that the overall quality of packed lunches was lower than school lunches. The content of energy and saturated fat was significantly higher in packed lunches compared with school lunches.[22] The sugar consumption almost doubled and the sodium consumption increased 50% in children who brought lunches from home. [23] Therefore, in addition to school meals, packed lunches also need improvements in order to promote healthy eating in children.

Physical activity component

Adult health, in particular body composition-related, is closely associated with the level of physical activity incorporated in childhood.[3] Children who are physically active are more likely to have a lower risk of hypertension, dyslipidemia, and insulin resistance. On the contrary, maintaining a sedentary lifestyle during childhood could lead to an increased risk of chronic diseases in later adulthood.[24] In addition, physical activity can enhance psychological and mental health in youth by improving self-esteem and self-competence as well as decreasing anxiety and depression.[25]

An effective pediatric obesity prevention and treatment program should combine the nutrition component together with the physical activity component. Some negative consequences may be related dietary restrictions such as decreasing basal metabolic rate could be compensated by incorporating regular physical activity.[3] In addition to increasing energy expenditure to create a caloric deficit, Long *et al.* (2002) observed that the regular physical activity can also increase the body's sensitivity to satiety signals to improve the short-term regulation of energy intake, which contributes to its positive influence on weight control.[26]

Children and adolescents aged 6-17 years are recommended to have 60 minutes or more physical activity per day.[27] According to the 2016 report card on youth physical activity, only 21.6% of children and adolescents aged 6-19 years met this current physical activity guideline.[28] Physical activity education and related environmental changes, such as increasing physical activity opportunities during school days or restructuring physical education curriculum, were incorporated in the majority of the multicomponent school-based interventions.[1] Although physical activity interventions alone may not provide a significant influence on improving weight status in youth, its positive impacts on behavioral changes, such as increasing physical activity time and reducing sedentary time, have been demonstrated by previous research.[1,2]

Sedentary behavior component

Sedentary lifestyle in childhood is linked to an increased risk of developing certain chronic diseases including type 2 diabetes, hypertension, and some cancers.[3] One thing to notice is that sedentary behaviors could co-exist with physical activities in one day.[29] In other words, children could participate in certain physical activities to meet the guideline; however, they might be sedentary the rest of the day. Therefore, preventing prolonged sedentary time is always recommended.[3] In addition, sedentary behaviors (such as television viewing) are usually coupled with eating, which increases the risk of positive energy balance to develop obesity.[3] Results from previous research showed children's dietary intakes might be influenced by food advertising during television viewing.[30] According to most updated guideline on children's media use by American Academy of Pediatrics (APP), media usage is limited to specific time based on age.[31] To be easily implemented, the *Let's go 5-2-1-0* program recommends screen time should be limited to two hours per day.[32]

However, children's screen time (aged 8-18 years) was estimated to be more than seven and a half hours per day.[33] Restricting screen time in youth together with promoting physical activities is necessary. AND mentioned in the position paper (2006) that fair evidence (Grade II) was found to support the effects of decreasing screen time (television/video) as part of multicomponent school-based interventions on weight status control in youth.[1]

Overview of SWITCH

SWITCH (School Wellness Integration Targeting Child Health) is a multicomponent, ecologically-based, web-enabled school wellness intervention. Schools were targeted in the intervention to provide the coordinating structure, motivation, and an effective channel to reach students and families. As reflected in the SWITCH mantra, which is to help students "*switch* *what they Do, View and Chew*", the program focused on improving three distinct behaviors known to be associated with the obesity development (i.e. physical activity, screen time, and dietary behaviors). The overall goal for behavioral changes in this program was to help children participate in moderate-vigorous physical activity for at least one hour per day, reduce screen time (including TV, video, and computer) to two hours or less per day, and increase fruit and vegetable consumption to 5 servings or more per day.

Originally, the SWITCH program was designed by the National Institute on Media and the Family, Minneapolis, MN, and it was first implemented in two school districts in Minnesota and Iowa in 2005. The article published by Eisenmann et.al (2008) described its rationale, design, and implementation in detail.[34] During the implementation cycle from 2005 to 2006, multiple-levels including family, school, and community were targeted. However, the family was treated as the primary target due to their direct influence on children's current and long-term behaviors.[34,35] Gentile and his colleagues reported the results of the program outcome evaluation in a paper published in 2009.[36] A modest program treatment effect on reducing screen time and increasing fruit and vegetable consumption was observed.[36] Furthermore, such effects still remained significant in the 6-month follow-up evaluation.[36] The program was recognized as a promising program by the *Let's move* campaign in 2010.[35]

In 2012, the SWITCH program was transferred to Iowa State University and began a series of restructuring and adaptations. The first step was to convert the program from a print-based to a web-based platform, since the high cost of printed resources/manuals (about $60 per student) had limited the program dissemination on a larger scale. Welk et.al (2015) conducted a formative evaluation to test if the web-based SWITCH program would work similarly compared to the original printed version.[35] The evaluation showed similar results for both impact and outcome measures between the web-based and the printed-based versions, supporting the utility of the online version as a more cost-effective method for larger program dissemination in the future.[35]

In this formative evaluation study, the fidelity of program implementation was found to be directly related to the degree of school engagement. [35] This means schools exerted a significant moderating influence on the program recruitment and facilitation. Therefore, the participating schools have become the key coordinating structure to promote the modifications in physical and social environments to which the children are exposed to, defining the program as a structural intervention.[37] To increase schools' engagement and promote environmental changes, three education modules for classroom, physical education (PE), and lunchroom have been built, utilizing the principles for behavioral changes and strategies for curriculum development.

Multiple studies have provided evidence to show the significance of modifying the school cafeteria environment on influencing students' eating behaviors during school meals.[12,18–20,38,39] Consistent with the school meal requirements and nutrition standards under the 2010 HHFKA, the SWITCH Lunchroom module provides resources and strategies, such as fruit and vegetable tastings, to help schools create environmental changes in the cafeteria to improve students' eating behaviors. French and Stables (2003) indicated that school environmental interventions could bring positive impacts on fruit and vegetable consumption.[10]

The SWITCH Classroom module includes 20 classroom activities to integrate academic concepts and the "*Do, View, and Chew*" themes. The classroom module was based on the established "*Move for Thought*" kit, which could incorporate physical activity in classrooms with any subject area. It has been distributed through the Iowa Team Nutrition program since 2012.

Previous work done by Vazou and Skrade (2017) indicated a significantly large improvement in math performance in the group that integrated physical activity.[40]

Education on energy balance is essential for helping weight control in youth. Chen et.al. (2013) demonstrated using educational technology (such as a Sensewear armband) in conjunction with a systematic educational approach was helpful to improve students' behaviors to live an energy-balanced lifestyle.[41] Based on the Social Constructivist Learning Theory, the SWITCH PE module developed scripted lessons, which are fun, physically active, and cognitively demanding, to teach students the principles of energy balance. There are 16 total lessons designed, but the PE teachers have the flexibility to choose 12 of them to teach during 12-weeks of program implementation.

Rapid improvements in digital technology provide opportunities for teachers to promote professional development, foster collaborations, and share resources.[42,43] A preliminary study (unpublished) done by the SWITCH team found the online learning community could have a positive influence on improving teachers' motivation and intention to integrate active learning strategies in the classroom. Therefore, a Community of Practice platform was developed in SWITCH to engage the classroom teachers, PE teachers, food service personnel, and other school wellness staff to help build the skills needed to carry out the programming.

Summary of Part I

Childhood obesity prevention and treatment interventions could be implemented in multiple settings. Among them, multicomponent school-based interventions have been shown to provide positive impacts on improving adiposity measures and obesity-related behaviors. Environmental changes have the potential to promote healthy eating and physical activity.

Part II: Influence of the School Cafeteria on Students' Dietary Behaviors and Nutrient Intake

Meal Requirements and Nutrition Standards for the National School Lunch Program

As mentioned previously, one of the benefits of delivering childhood obesity prevention programs in school settings is that schools can provide a convenient platform to implement policies and regulations consistently for supporting healthy lifestyles. Among various school environments to which the students are exposed daily, the cafeteria possesses a unique and significant role in influencing the dietary behaviors of students.

Established under the *Richard B. Russell Nation School Lunch Act* in 1946 and administered by the Food and Nutrition Service (FNS) of the United States Department of Agriculture (USDA) at the federal level, the National School Lunch Program (NSLP) operates in public and nonprofit private schools and residential childcare institutions. Largely increasing the number of students being served from 7.1 million at the start of its creation in 1946 to 30.4 million in 2016, the NSLP has become the second largest federal food and nutrition assistance program.[44]

Because the NSLP was established shortly after World War II and the Great Depression, the purpose of this program at the beginning was to reduce hunger and provide a safety net for children in need. Until 1994, to qualify for receiving the federal reimbursements for school meals, schools only needed to meet the prescribed meal patterns with the overall goal of providing 33% of the Recommended Dietary Allowance (RDA) for energy and nutrients at lunch and 25% of RDA at breakfast.[45] Four components out of five food items were required in a traditional meal pattern for lunch: a meat/meat alternative, a grain product/bread, two servings of different fruits and/or vegetables, and fluid milk.[45]

As the prevalence of pediatric obesity increased dramatically in the U.S. during recent years, providing children with nutrition-balanced meals has become the current focus in the NSLP.[46] Previous research provided consistent evidence to show the nutrient intake and meal patterns in youth could not meet the recommendations and standards.[47] Gleason and Suitor (2001) analyzed children's dietary intake and its relationship with school meal participation using data from the 1994-1996 Continuing Survey of Food Intake by Individuals (CSFII).[48] They found the intakes of folate, zinc, magnesium, calcium, vitamin A, and vitamin E were at a high risk of being inadequate in many children, especially in teenage girls.[48] On the other hand, the intakes of total fat, saturated fat, and sodium exceeded the upper limit of recommendations.[48] Furthermore, only 2% of children met the requirements of servings for all five major food groups recommended by the Food Guide Pyramid.[48] Comparing the nutrient intake between NSLP participants and nonparticipants, the mean intakes of food energy and many nutrients including calcium, magnesium, phosphorus, and zinc were higher in NSLP participants both at lunch and over 24 hours.[48] The consumption of vegetables, dairy, and meat/meat substitutes was also higher in NSLP participants.[48] Therefore, the NSLP provided a positive influence on children's dietary intake, and continuingly improving the quality of school meals may have the potential to promote the overall health in children and adolescents.

In November 1994, the *Healthy Meals for Healthy Americans Act* (P.L. 104-448) was passed by Congress, which required the meals served in school meal programs(including NSLP and School Breakfast Program (SBP)) to be consistent with the *Dietary Guidelines for Americans 1995*.[45] To assist implementing this law, a USDA policy known as *School Meals Initiative for Healthy Children* (SMI) was developed and became effective starting in the school year (SY) 1996-1997. SMI established new nutritional standards for school meal programs and provided four alternative menu planning systems to help school achieve these nutritional goals.[45] To be consistent with not only the RDA, but also the *Dietary Guidelines for Americans 1995*, school lunch programs should provide meals containing 33% of RDA for calories, protein, vitamin A, vitamin C, calcium, and iron. Total fat content in a school lunch should be controlled at 30% or less of the total energy, and the calories from saturated fat should be less than 10%. Although reducing sodium and cholesterol and increasing fiber in school lunches was also encouraged in SMI, schools were not required to meet certain quantitative targets for such nutrients. To meet the nutrient standards, a lunch menu usually offered an entrée, milk, one or more side dishes including bread/grain products, fruits, vegetables, and desserts.

Because of the *2004 Child Nutrition and WIC Reauthorization Act* (P.L.108-265), as well as the need to promote consistency with the latest *Dietary Guidelines for American* and *Dietary reference intakes* (*DRIs*), updating and revising the meal requirements and nutrition standards was put on the agenda. In 2010, the National Academy of Medicine, formally called the Institute of Medicine (IOM), published an updated version of *Nutrition Standards and Meal Patterns* for school meal programs (abbreviated as 2010 IOM recommendations here afterwards in this dissertation). The recommendations for menu planning emphasized increasing the amounts of whole grains, fruits, and vegetables as well as decreasing the amounts of sodium and saturated fat offered in school lunches. A target range (i.e. minimum and maximum level) for energy was also set.[46] The detailed menu planning recommendations are presented in Appendix A. The new meal requirements and nutritional standards came into effect beginning in the SY 2012-2013.

Students' Dietary Behaviors and Nutrient Intake in School Lunches

Sponsored by the FNS, School Nutrition Dietary Assessment (SNDA) is an ongoing monitoring collection study, which is conducted every five years and provides national up-to-date information on nutritional quality of school meals that are offered to, served to (i.e. selected by students), and consumed by students.

The first SNDA study, SNDA-I, examined the nutritional quality of school meals and students' dietary intake in the SY 1991-1992.[49] The findings of this study demonstrated the amounts of total fat, saturated fat, and sodium offered in school meals were higher than the recommendations, which helped prompt the updates of the policies and regulations and the establishment of the SMI.[49]

In the SY 1998-1999, SNDA-II was conducted and school menu data was analyzed to check the compliance of school meals with the nutritional goals set in the SMI.[50] The percentage of calories from fat in NSLP lunches was estimated to be 33% to 34%.[50] Although lower than the 38% estimated in SNDA-I, [44] it still exceeded the upper limit of 30% that was recommended in the SMI.[49,50] Considering the SMI became effective in 1996, the data collection time in SNDA-II was still in the early phase of SMI implementation. In addition, only school menu data was collected in this assessment, and no students' dietary intake data was included.

Compared to SNDA-II, the design and methods used in SNDA-III for data collection improved greatly. Using a well-designed multi-stage sampling method, about 130 school food authorities, 398 schools, and approximately 2,300 students across the nation participated in the telephone or in-person interviews, surveys, or two-day 24-hour dietary recalls in SNDA-III data collection in 2004.[51] The assessment reported lunches offered in over 85% of schools participating in the NSLP met the nutritional standard for each of the key nutrients including protein, calcium, iron, vitamin A, and vitamin C.[52] The percentage of calories from total fat was estimated to be 34% in a school lunch, remaining the same as the findings in SNDA-II. [52] However, the percentage of schools meeting the SMI saturated fat standard doubled from the SY

1998-1999 in SNDA-II to the SY 2004-2005 in SNDA-III.[52] The report of SNDA-III also indicated that compared to nonparticipants, NSLP participants had higher intakes of several nutrients at lunch, including protein, calcium, phosphorus, potassium, riboflavin, vitamin A, and vitamin B12.[52]

The latest SNDA study, SNDA-IV, collected data from samples of school districts and schools national-wide in the SY 2009-2010.[21] Compared to the findings in SNDA-III, schools had made significant improvements in meeting the SMI standards for total fat and saturated fat. Among elementary schools, the percentage of schools that served an average school lunch meeting the SMI total fat standard increased from 26% in the SY 2004-2005 to 34% in the SY 2009-2010, and the percentage meeting the SMI saturated fat standard increased from 34% to 53% during the same two periods.[21] However, only 14% of the schools offered school lunches that could meet all of the SMI nutritional standards, and only 7% of the schools served school lunches meeting all standards.[21] The nutritional goals for calories, total fat, and saturated fat were still the most challenging ones.[21] The findings in SNDA-IV not only provided evidence to show the efforts that schools made to achieve the SMI nutritional goals, but also served as a baseline marker for identifying future improvements after implementing the new 2010 IOM recommendations starting from SY 2012-2013.

To better understand the influence of 2010 IOM recommendations on students' dietary behaviors and nutrient intake at school lunches, primary research studies were retrieved from PubMed--a scientific research website. The key search term used was "national school lunch program", and only studies from English-language peer-reviewed journals published within 5 years were selected. At first, 116 articles were identified. After further reading through the abstracts and searching for key terms, only the ones studying the students' dietary behaviors (such as the food selection, wastes, and consumption), or nutrient intakes, in U.S. NSLP meals remained. The studies evaluating school lunches before the implementation of 2010 IOM recommendations were excluded. Finally, six research articles were selected and summarized in Table 2.1.

Overall, the new school meal standards provided positive impacts on improving the nutritional quality of school meals as well as promoting the students' dietary behaviors and nutrient intake during school lunches. Two studies, Cohen et al. (2014) and Schwartz et al. (2015), evaluated the percentages of selection and consumption for each meal component in a typical school lunch (i.e. including entrée, fruits, vegetables, and milk), and the results were similar between the two studies.[53,54] The percentage of students selecting fruits increased significantly from the time of pre-implementation of new standards to the time of post-implementation. However, neither the fruit consumption percentage among students who selected fruits, nor the quantity of fruit consumed per student, changed significantly.[53,54] In contrast, the percentage of students selecting vegetables remained the same during the data collection period, or even decreased slightly. But both the vegetable consumption percentage and the quantity of vegetables consumed per student increased significantly.[53,54] The study conducted by Cullen et al. (2015) also measured the selection and consumption patterns during school lunches, but using more detailed classifications for meal components.[56] The percentages of selection and consumption, as well as the consumed amount were measured for energy, fruit, juice, each type of vegetable (such as dark green, red-orange, starchy, legumes, and others), total grains, whole grains, protein, and milk.[56] Amin et al. (2015) reported although the quantity of

Table 2.1. Studies related to the students' dietary behaviors and nutrient intake after implementing the 2010 IOM recommendations

Reference	Data collection time	Students and School included	Dietary assessment method(s)	Key findings
Byker et al.(2014) [55]	5 consecutive school day (1 full week) in March, 2013	1 prekindergarten and 5 kindergarten classes in 1 public elementary school	Weighing method	Only wasted percentages of meal components were estimated: 45.3% of total food and beverage was wasted during the full school week; The percentage of waste for each meal component from the largest to smallest was vegetable (51.4%), main entrée (51%), milk (45.5%), and fruit (33%).
Cohen et al.(2014) [53]	2 days per school in the fall of 2011 (pre-implementation) and 2 days per school in the fall of 2012 (post-implementation)	All students (n=1030) in grade 3-8 in 4 elementary/K-8 schools within 1 school district	Weighing method	Selection (%) and consumption (% and quantity) were estimated for each meal component: Entrée: all students selecting entrée pre- and post-implementation; the percentage of entrée consumed significantly increased by 15.6. Fruit: the percentage of students selected fruit increased significantly by 23; the consumption of fruit did not change significantly. Vegetable: the selection percentage changed not significantly; consumption increased by 16.2%.

Table 2.1. continued

Reference	Data collection time	Students and School included	Dietary assessment method(s)	Key findings
Schwartz et al.(2015) [54]	1 day per school in spring, 2012(pre-implementation), and in spring, 2013 and 2014 (post-implementation)	All students in grade 5-7 in 12 K-8 schools within 1 school district	Weighing method	Selection (%) and consumption (%) were estimated for each meal component: Entrée: the selection and consumption percentage both increased significantly from 2012 to 2014 Fruit: the selection percentage increased significantly by near 13%; although consumption percentage did not change a lot, it remained high at 72-74%. Vegetable: the selection percentage decrease slightly from 2012-2014, but the consumption increased by 18%.
Cullen et al.(2015) [56]	8-10 observations per grade per school in spring, 2011 (pre-implementation), and in spring, 2013 (post-implementation)	All students (n=472 in 2011 and n=573 in 2013) in 8 elementary schools within 1 school districts	On-site visual estimation method	Selection (%) and consumption (% and quantity) were estimated for detailed meal component: The selection percentage increased significantly from 2011 to 2013 for fruit, 100% juice, total fruit plus 100% juice, other vegetables, whole grains, protein food and milk; but decreased for starchy vegetables. The only significant change (decrease) in consumption percentage was in legumes. The quantity of consumption increased significantly for total fruit plus 100% juice and red vegetables; but decreased significantly for legumes, protein food, and other vegetables.

Table 2.1. continued

Reference	Data collection time	Students and School included	Dietary assessment method(s)	Key findings
Amin et al.(2015) [57]	10 school visits in spring, 2012 (pre-implementation), and 11 school visits in spring, 2013 (post-implementation)	Students in grade 3-5 in 2 elementary schools	Weighing method; On-site visual estimation method; Photo-based visual estimation method	The percentage of trays selecting fruit and vegetable and the quantities of fruit selection, consumption, and waste were measured: the percentage of fruit vegetable selection increased significantly from 84 to 97 from 2012 to 2013; fruit and vegetable selection amount increased significantly from 0.69 to 0.89 cups, but the consumption decreased from 0.51 to 0.45 cups; wastes increased from 0.25 to 0.39 cups.
Johnson et al.(2016) [58]	Food production record collected daily from January, 2011 to January, 2014	All students 3 middle schools and 3 high schools within 1 school district	Food production record	Nutrient density, energy density, and NSLP participation rate were measured: mean adequacy ratio of school meals selected by students increased from 58.1 pre-implementation to 75.6 post-implementation; energy density decreased from 1.65 to 1.44; school lunch participation remained at 46% to 47%.

fruits and vegetables selected by each student increased from pre-implementation to post-implementation, the amount of fruits and vegetables wasted per student also increased significantly at the same time.[57] Therefore, the actual consumption quantity decreased.[57] The study from Byker et al. (2014) also pointed out that the large food waste was one of the biggest challenges faced by the NSLP.[55] After a full-week examination of school lunches, they found that an average of 45.3% of a school meal was wasted, and among all meal components, vegetable was the one wasted in the greatest amount (51.4%).[55] In the study led by Johnson et al. (2016), data from food production records provided positive evidence to show that the nutrient density increased while energy density decreased after the implementation of the 2010 IOM recommendations.[58]

As discussed above, most of the studies indicated the new nutritional standards might bring a positive influence on improving students' dietary behaviors and nutrient intake as well as promoting the quality of school meals offered to students. However, the school meals that were actually selected and consumed by students hardly met all the nutritional standards, which was particularly true for fruits and vegetables. According to the 2010 IOM recommendations, 2.5 cups of fruit and 3.75 cups of vegetable per 5-day week were recommended, which was converted to 0.5 cups and 0.75 cups, respectively, as the minimum daily requirements.[46] The data in a study conducted by Cohen et al. (2014) showed the mean fruit and vegetable consumption per school lunch was 0.42 cups and 0.31 cups, respectively, both lower than the recommendations.[53] Cullen et al. (2015) estimated the fruit consumption as high as 0.6 cups per school lunch; however, their estimation of vegetable consumption was still as low as 0.35 cups.[56] Therefore, strategies to promote fruit and vegetable selection and consumption should be further considered.

Strategies to Increase Fruit and Vegetable Selection and Consumption at School Meals

Practices and strategies deployed in multicomponent school-based interventions, especially the ones to promote environmental changes in school settings (such as in the school cafeteria), were shown to be effective in increasing fruit and vegetable consumption.[10]

Increasing the variety of fruits and vegetables has the potential to increase fruit and vegetable consumption. In 2013, a memo was issued by the USDA FNS to all state and regional directors encouraging school food authorities to incorporate salad bars in their food service operation due to its ability to provide a wider variety of fruits and vegetables.[59] To evaluate the influence of salad bars, Adams and colleague (2005) conducted a study to measure and compare fruit and vegetable consumption among 294 students from four elementary schools.[60] Two of them provided salad bars, and the other two only provided pre-portioned fruits and vegetables.[60] Although the results showed there was not a significant association between the presence of salad bars and an increase in fruit and vegetable consumption, the variety of fruit and vegetable items in the salad bar had a positive relationship with their consumption ($p<0.05$).[60] In addition to the variety of items presented in a salad bar, the location of a salad bar is another influencing factor for fruit and vegetable consumption. In a later study also led by Adams and colleague (2015), students from six middle schools with salad bars either inside or outside of the serving line were measured for their selection, consumption and waste of fruits and vegetables.[61] The study found salad bars inside the serving line led to an increase in fruit and vegetable selection and consumption and a decrease in the waste.[61]

Hakim and Meissen (2013) examined the effects of an intervention on fruit and vegetable consumption, in which an active, forced choice was introduced into the school lunch service.[62] Fruits or vegetables were designated as the "choice item" on each day, and the students could choose their preferred choice item from three options, together with a standard-sized non-choice item on their tray. For example, if one day is a "fruit choice" day, students could choose their preferred fruit item from apricots, bananas, and grapes, but have no choice for vegetables--all students received the same vegetable item of the same size.[62] The data indicated the consumption of fruits and vegetables each increased by 15% during the implementation of this intervention, which provided support for using the active choice as a potential strategy to promote students' dietary behaviors.[62]

Presenting the food items in a more attractive or creative way may have positive impacts on improving fruit and vegetable consumption, such as pre-slicing the fruits, or using attractive names. Slicing some fruit items is a simple and low-cost food preparation technique, which is more appealing to younger children since it makes eating easier and tidier. Wansink et al. (2013) reported the sales and consumption increased in schools serving pre-sliced apples, and their waste also decreased.[63] However, the impact of pre-slicing fruits may vary by food items. In another study, the influence of slicing apples and slicing oranges on students' selection and consumption was evaluated seperately.[20] Slicing oranges was associated with increased selection and consumption, however, such an increase could not be found for sliced apples.[20] Also, the technique of slicing may have a greater impact on students at younger age.[20] Selective use of attractive names can promote healthy eating effectively and persistently in elementary schools. It was found in a study that using an attractive name such as "X-ray Vision Carrots" led to the consumption of carrot doubling among elementary students, compared to using the normal name or without using any name.[64]

Fruit and vegetable tasting, which encourages students to expose themselves to new food items has been used in some school-based interventions to increase fruit and vegetable consumption. Lakkakula and colleague (2011) designed a study to evaluate the influence of tastings on the students' liking for targeted fruit and vegetable items.[65] During an eight-week period, four fruit/vegetable tastings were provided to students every other week, and the tasting experience was measured by a survey.[65] The results showed students who disliked the targeted fruit and vegetable items at the beginning improved their liking for all items after eight weeks.[65] Such improvements still maintained at the 4- and 10-month follow-up assessments.[65]

Persons who have a close relationship with students at school, such as teachers and food service personnel, also have the potential to affect students' eating behaviors. Schwartz (2007) indicated in a study that the fruit selection was 30% higher in schools in which the food service personnel provided a verbal prompt (e.g. "would you like fruit or juice?").[38] It was estimated in another study that the strategies of using modeling, prompting, and larger and more varied prizes (such as toys and coupons) resulted in fruit and vegetable consumption increasing from 7% to nearly 40%.[66]

Summary of Part II

Legislations and policies used to set the standards for school meals and food service practice continued to be updated in order to keep consistent with the updating dietary guidelines and references. To better improve the nutritional quality of school meals, new meal requirements and nutritional standards were published in 2010, and became effective in SY 2012-2013. The dietary assessment data provided evidence to show the schools' effort on improving the quality of school meals to achieve the nutritional goals, and the students' dietary behaviors and nutrient intake were improved as well. However, strategies are still needed to further promote healthy eating among children, especially to promote fruit and vegetable consumption. Increasing the variety of fruits and vegetables, providing active choices to encourage the selection, pre-slicing some food items, using attractive names, providing tastings, teacher's modeling, and giving incentives or verbal prompts are some commonly used strategies in schools to increase the consumption of fruits and vegetables.

Part III: Food Visual Estimation Method

As discussed in Part I, school-based childhood obesity prevention programs could bring positive impacts on promoting a healthy life-style in children, including increasing their fruit and vegetable consumption and physical activity level. To evaluate the effects of such interventions on children's behaviors as well as to have a better understanding of dietary intakes and nutrition status in youth, using a valid dietary assessment method is critical. Therefore, in this part, several dietary assessment methods that are commonly used in youth populations will be discussed. Self-reported dietary assessment method and the weighing method were analyzed first, considering their wide applications in measuring dietary intake. Their validities and weaknesses are also summarized, which leads to our focal point--the visual estimation method. As a rapidly developing dietary assessment method, visual estimation has been applied in many studies, especially in school-based programs. School plate waste studies using visual estimation as the method to measure students' dietary intake are analyzed and summarized. Finally, the challenges in this area in the field of nutrition were identified.

Self-reported Dietary Assessments

Self-reported dietary assessment methods, such as 24-hour dietary recall, dietary records, Food Frequency Questionnaire (FFQ), and diet history, are commonly used to measure dietary intake and evaluate the nutrition status in adults. The dietary records approach asks the respondents to write down the amounts of food and beverage that are consumed during a designated period, typically consecutively and no longer than seven days.[67] To avoid the reliance on memory and increase the accuracy of reporting, dietary records are recommended to be completed by the respondents at the time of eating.[68] One potential disadvantage of the dietary record approach is the limitations of use in some populations (e.g. low literacy, children, and elderly). In addition, this method requires the respondents to keep recording for a certain period, which could be burdensome and result in more incomplete records and poor data quality.

To overcome some of the challenges faced by dietary records, the 24-hour diet recall method is an alternative used to collect children's dietary intake data. During the structured interview, a trained nutritionist or other professional asks the respondent to provide detailed information about all food and beverages they consumed during the preceding day or preceding 24 hours.[68] Currently, the USDA automated multiple-pass method is the state-of-the art protocol due to its advantage of reducing bias.[69]

Unlike diet records and 24-hour dietary recall which can obtain the respondents' actual dietary intake for one day or multiple days, FFQ acquires the information about the respondents' usual frequency of consumption of certain items from a food list over a defined period in the past week, month, or year.[68] The portion size questions are usually incorporated as well.[68] FFQ is widely used in epidemiology studies due to its easy implementation and low-cost. However, detailed dietary information cannot be obtained by this method, so the accuracy of estimations on dietary intake might be lower than that in diet records and 24-hour dietary recall.[68]

In a general sense, any method containing reports of past diets could be called dietary history. In the area of dietary assessment, the term *diet history* refers to the approach established by Burke, which is collecting data to obtain information about the frequency and quantity of food intake as well as details about the food/meal characteristics.[70] Three elements are included in Burke's dietary history method: a detailed interview to know the usual pattern of eating, a food frequency checklist to know the usual food intake, and a 3-day dietary record.[70] Considering that a great deal of burden might be put on the respondents, this method is not quite practical and used rarely in children and adolescents.[67]

Although self-reported dietary assessment methods are widely used in many studies, their validities have been criticized by researchers. Many factors might influence the quality of data, such as the respondents' willingness to report, the respondents' ability to remember the food consumed and to estimate portion size, as well as the respondents' age and weight status.[71] Doubly labeled water (DLW), which typically estimates people's total energy expenditure (TEE) over 7-14 days, is considered to be the gold standard method to validate the measurements of energy intake (EI) by other dietary assessments. In a review article, fifteen studies were evaluated, which intended to validate the dietary assessment tools used in youth population by comparing the EI measured by the assessment tool to the TEE estimated by the DWL.[72] The results indicated some degree of misreporting occurred in all types of self-reported dietary assessments: significant over-reporting was found for 24-hour dietary recall and FFQ while significant under-reporting existed in diet records.[72]

Some physical and psychological characteristics of children and adolescents make it even harder and increase the bias when applying the self-reported dietary assessment methods to youth. A review paper published by Livingstone and Robson (2000) summarized reasons hindering the self-reported dietary assessments applied to children and adolescents.[71] Children's limited knowledge of food, limited memory, low literacy skills, and rapidly changing food habits make the report of dietary intake hard to complete. Hence, their parents or other caregivers may report for the children or finish the reporting together with their children, which may potentially increase the reporting bias.[71] Since cognition develops as the children grow older, it is no longer a problem for adolescents to self-report. However, peer pressure and beginning to have an awareness of body image make the adolescents reluctant to report their dietary intake honestly.[71] To improve the quality of dietary data, alternative methods needed to be applied to youth populations.

Weighing Method

Weighing Method, i.e. direct weighing of food waste, serves as the gold standard method to measure food waste and consumption, and has been widely used in plate waste studies. The procedure of weighing method is straightforward. Before the meal starts, several sample trays are gathered to weigh food items separately, and the average weight for each food item is recorded. After the meal, the leftover on students' individual trays are weighed again for each food item.[73] The consumption of individual food per student can be calculated by subtracting the food waste amount from the average weight of food served to a student before eating. In a systematic review by Shanks and Serrano (2017), the plate waste studies conducted in the NSLP from 1978 to 2015 were selected and summarized.[74] Among the 53 studies included in this review, 23 plate waste studies selected direct weighing as the measurement methodology.[74] Twelve studies weighed all food items on the trays, whereas the others only focused on specific food items or components.[74] Fruits and vegetables are the most common items to be measured. Their wasted amounts were reported in 16 studies in this review article.[74] The food waste and consumption measured or calculated by the weighing method can help understand the influence from nutrition education, food service practice, lunchroom environment, and food accessibility on students' dietary behaviors.[74]

Using this procedure to weigh each food item on individual trays could provide the most accurate and detailed information about the dietary intake at the individual level. However, it requires a large space to hold the trays and weigh the waste. The normal lunch pattern may be disturbed, resulting in the unintentional influence on students' dietary behaviors.[73] In addition, the procedure is very time-consuming and costly. All of these disadvantages limited the applications of the weighing method, especially in the large-scale plate waste studies.

In the face of such challenges, the method of aggregate measurement was employed in some studies as an improvement to the standard weighing method.[74] The procedure of aggregate measurement, which only weighing the total waste of the measured population (some studies may weighing total waste across different food items), is much faster than the standard weighing method with weighing each food item on individual trays. The mean or total waste can be measured accurately by the aggregate measurement, however, dietary information at the individual level cannot be determined.[73] For example, we cannot know whether there is a difference on food waste between males and females when only aggregate wasted amounts are measured. Therefore, flexible, non-interruptive, and cost-effective dietary assessment methods which not only provide accurate measurements at the individual level but also are appropriate and practical in youth are highly demanded.

Visual Estimation Methods

Due to many advantages, such as high-flexibility, cost-effectiveness, easy implementation, and unobtrusiveness, the visual estimation method attracted more in recent years. Visual estimations could be performed either on-site through direct observation or remotely through comparing before- and after-eating photos. If visual estimations are conducted on-site, trained researchers come to the school cafeteria before mealtime to be familiar with the portion sizes of targeted food items that will be assessed. After meal, students' trays with leftovers are gathered in a station, and the researchers estimate the amounts of food waste in valid increments.[74] The on-site visual estimation method reduces the burden put on the respondents compared to self-reported dietary assessment methods, and is cost-effective and time-saving compared to the weighing method. Visual estimation methods have been widely used in studies evaluating nutrient intake and dietary behaviors conducted in schools or other public settings [18,74–76]. However, several disadvantages still exist. First, a certain space or a station is needed in school cafeterias to hold the trays for visual estimations, which may be obtrusive to the normal school lunch pattern.[77] Second, in order to estimate the amount of food wasted after eating, researchers need to memorize the initial portion sizes before the meal was served. The variations in initial portion sizes increases the estimation difficulty, and it is impractical to perform the on-site visual estimations for self-served food items without a standard initial portion size (such as fruits and vegetables selected from the salad bar). Third, on-site visual estimations are required to be finished within a limited time period, which increases researchers' pressure and anxiety, and may potentially influence the accuracy of their estimations.[77]

The widespread use of digital technology and wireless communication devices largely improved the dietary assessment methods. In photo-based visual estimations, photos are taken for individual trays with the selected food items before meal, and then photos are taken again after eating. By comparing before- and after- eating photos for the same tray, trained researchers estimate food waste and consumption after the time of data collections without any time pressure.[77] Some additional advantages are provided by the photo-based visual estimation method when compared with on-site visual estimation method, including increased flexibility, less burden on researchers, and more convenient access to and storage of data.

Photo-based visual estimation has been shown to be a valid and reliable dietary assessment method. Williamson, Martin, and their research team made contributions in developing and applying the photo-based visual estimation method. In their paper published in 2003, the photo-based visual estimation method was described in a detailed way, and it was the first time to demonstrate its validity by comparing it with the weighing method and on-site visual estimation method.[78] The results showed the estimates of amounts of food selection, waste, and consumption were highly correlated with the measurements by the weighing method.[78] When comparing photo-based estimations with on-site estimations, Bland-Altman regression analysis indicted the two methods yielded comparable results.[78] In this study, the photo-based visual estimation method was applied to the university cafeteria.[78] The research team then expand its application and used this method in many other environments or populations, such as in soldiers during their basic combat training, in children or elementary-based school programs, in preschool-aged children enrolled in Head Start, or in free-living conditions.[11,77,79–81] All studies provided evidence to support the photo-based visual estimation as a valid and reliable dietary assessment method in various populations and environments.

The weighing method and DLW are the two most common standard methods used to test the validity of visual estimations. In a study comparing the energy intake estimated by the method of photo-based visual estimations with the method of DLW, a significant mean underestimate of 222 kcal per day was found in visual estimations regardless of the energy intake.[82] The serving-style (i.e. self-served or food service personnel-served) may influence the accuracy of visual estimations. Olafsdottir and colleague (2016) conducted a study to compare the visual estimations with the measured weights of plate waste in two elementary schools across five school days, in which one school was self-served and another was food service personnel-served.[83] Although the estimated and weighed amounts were highly correlated, indicating the validity of the photo-based method, the serving styles did affect the efficacy of this method: the rate of acceptable estimations was higher in the school with the style of food service personnel-served (95%) than the school with the style of self-served (73%).[83] Another study by Martins et al. (2014) came to a similar conclusion, which indicated the visual estimation method was not as accurate as the weighing method if the initial portion sizes varied a lot.[84]

As to the comparisons between on-site and photo-based visual estimations, results from different studies did not come to an agreement. In several studies from Williamson and Martin's research team as discussed previously, high correlations (calculating Pearson correlations or using Bland-Altman analysis) were found between on-site and photo-based visual estimations.[78,85] Their conclusion was supported by a study from Parent et al. (2012), in which the regular and modified-texture main plate food waste in a continuing and long-term care setting were estimated using both on-site and photo-based methods.[86] Intra-class correlation (ICC) for absolute agreement was calculated to show the intermodal reliability, and results indicated a high agreement between the two methods (ICC = 0.9 and 0.88 for regular and modified-texture food, respectively).[86] However, results from Hanks et al.'s study (2013) were very different. The estimates of school lunch waste using three visual estimation methods (i.e. on-site visual estimations using quarter system, on-site visual estimations using half system, and photo-based visual estimations using 10% scale) were each compared with the weighing method.[87] Inter-method reliability was higher in both on-site visual estimations regardless of the rating system (r =0.9 and 0.83 for quarter system and half system, respectively) than the photo-based method (r=

0.48).[87] The inter-rater reliability was lowest in the photo-based method (r=0.57).[87] One possible reason for the poor performance of the photo-based visual estimation method in this study might be its inability to see the inside of packages, containers, or cartons included in this study.[87] However, different rating scales (i.e. quarter system, half system, 10% scale) were also used in this study, which may be a confounding factor to potentially influence the accuracy of estimations. Thus, the variations observed in the accuracies between on-site and photo-based visual estimations in this study may not be related to the method, but due to the rating scales used. The comparisons between different rating scales will be discussed later.

Applications of the Photo-based Visual Estimation Method in School Plate Waste Studies

Plate waste studies conducted in the NSLP using the photo-based visual estimation method were searched on scientific websites including PubMed and Science Direct, using the key words *school lunch, plate waste, digital*, and *visual*. Articles using the photo-based visual estimation method, peer-reviewed, written in English, conducted in the U.S., and covering the NSLP were selected. Studies using a combination estimation method, which either combined the photo-based estimations with the on-site observations, or combined the visual estimations with the weighing method, were excluded. Twelve articles published after the year 2000 were selected and summarized in Table 2.2.

The use of digital technology has become more widespread in the past 20 years. Williamson et al. first described the photo-based visual estimation method in 2002 and tested its validity compared to the weighing method in 2003.[78,88] Therefore, the applications of the photo-based visual estimation method in plate waste studies were mostly published after the year 2000. In most studies, the percentage of food selection and waste were estimated by comparing before- and after-eating photos with the reference photos. Then, the percentage of consumption was calculated by subtracting the waste percentage from the selection percentage. If the amounts and nutrition information (i.e. energy, macro- and micro-nutrients) for the food items were available, such values could be calculated for food selection, waste, and consumption. Directly estimating the percentage of consumption was only found in two studies. Both were from a large project evaluating the effects of the Farm to School program and both were published by Bontrager Yoder et al in 2014.[89,90] Among the 12 studies, the plate waste measurements were primarily conducted in elementary school cafeterias. Only three studies evaluated the plate waste in middle school settings.[91,93,97] The research purposes varied in these studies, including to assess the validity and reliability of photo-based visual estimations applied to a specific population or a specific type of meal,[91,95,99] to examine the school lunch pattern and compare with the nutrition standards,[92,93] or to evaluate the impacts of certain programs or interventions on the students' eating behaviors and nutrient intake.[12,89,90,94,96–98]

As mentioned earlier, the validity of the photo-based visual estimation method was first reported in a study by Williamson et al. (2003).[78] This study was conducted in university cafeterias. Further testing was needed to determine whether this method was still valid and reliable to measure the dietary intake in children. A study from their research team published in 2006 provided evidence for this.[91] In this study, ICCs were calculated for estimations of food selection, waste, and consumption to test the reliability, and results showed the ICCs for all three values were high (r= 0.95, 0.95,0.93, respectively).[91] Typically, the validity of the photo-based

Table 2.2. Summary of plate waste studies in schools after the year 2000 using the photo-based visual estimation method

Reference	Study purpose	Participants	Days of data collection	Rating scale	Outcome measurements	Key Results
Martin et al.(2006) [91]	To test the validity and reliability of photo-based visual estimation method in school cafeteria; also test the effects of second serving on food intake	6^{th} grade students (n=43) from 1 middle school	5 consecutive days	10% increments [a]	The percentage and energy (kcal) of food selection, waste, and consumption (compared to reference portion); Percent body fat; BMI; CDI score [b]; RSES score [c]	Reliability: ICC for food selection and wastes is 0.95; for consumption is 0.93. Convergent validity: Pearson correlation is significant between BMI percentile and estimated food consumption (p<0.01). Discriminant validity: Pearson correlation is not significant between either CDI or RSES score, and estimated food consumption (kcal). Second serving: increase both food selection and waste significantly (p<0.05); the consumption was not significantly different
Martin et al.(2010) [92]	To examine the school lunch pattern to test whether it met the SMI standards and IOM recommendations	4-6^{th} grade students (n=2049) from 33 elementary schools	3 consecutive days	10% increments [a]	The percentage, energy (kcal), and macro- and micro-nutrients information of food selection, waste, and consumption (compared to reference portion); BMI;	SMI standards: 77% met energy; all met the protein; less than 30% met fat and saturated fat. BMI had no influence. IOM recommendations: 16% met energy range; 58% met total fat range; less than 30% within the saturated fat target. Mean fat selection and consumption was 33.3% and 34.3%.

Table 2.2 continued

Reference	Study purpose	Participants	Days of data collection	Rating scale	Outcome measurements	Key Results
Smith and Cunningham-Sabo (2013) [93]	To evaluate the school lunch selection and consumption pattern and compare with NSLP standards (2004 CNR guidelines [d] and HHFKA guidelines)	1-5th grade students (n=535) from 3 elementary schools and 6-8th grade students (n=364) from 2 middle schools	5 days per elementary school and 4 days per middle school	10% increments [a]	The percentage of students selecting each menu item; The percentage of food waste The energy and nutrients information of food consumption;	Elementary schools: 45% students selected a vegetable; more than 1/3 grain, fruit, and vegetable were wasted Middle schools: 34% students selected a vegetable; near 50% fresh fruit, 37% canned fruit and 1/3 vegetable were wasted. Less than ½ of students met the recommendations for iron, vitamin A and C.
Williamson et al.(2013) [12]	To evaluate the effects of two interventions (Wise Mind and LA Health) which promote school cafeteria environmental changes on students' nutrition and healthy eating	Wise Mind: 6th grade students from 4 elementary schools (n=670) LA Health: 4-6th grade students (n=2097) from 17 elementary schools	3 consecutive days per school both at baseline and end of the study	10% increments [a]	The percentage, energy (kcal), and macro- nutrients information of food selection, waste, and consumption (compared to reference portion); HEI score [e]; BMI;	Improved nutrition was reported in the in the intervention group in both studies, including decrease selection and intake of total energy, fat, saturated fat. In LA Health study, HEI score improved significantly for food selection ($p<0.01$) and intake ($p<0.05$) in intervention group, but decreased significantly in control groups ($p<0.05$).

Table2. 2. continued

Reference	Study purpose	Participants	Days of data collection	Rating scale	Outcome measurements	Key Results
Bontrager Yoder et al. (2014) [89]	To evaluate the effects of Farm to School (F2S) program in Wisconsin on fruit and vegetable intake in students	3-5th grade students (n=850) from 8 elementary schools	4 days per school both at baseline and follow-up	Quarter system [f]	The percentage and amounts (cups) of food selection and consumption; The scores of knowledge, attitude, exposure, liking, and willingness (from Knowledge and Attitude survey); Fruit and vegetable intake (from FFQ)	The program may have no significant effects on overall dietary patterns (FFQ), but can significantly decrease the percentage of students not selecting and consuming fruit and vegetable items from baseline to follow-up ($p<0.05$). The fruit and vegetable consumption increased among those with the lowest intakes (FFQ). Willingness, knowledge and fruit and vegetable selection were positively related to increasing prior F2S exposure
Bontrager Yoder et al. (2014) [90]	To identify the relationship between the fruit and vegetable (FV) intake and the total energy intake	3-5th grade students (n=845) from 8 elementary schools	4 days per school	Quarter system [f]	The percentage, amounts (cups), and energy of food selection and consumption;	Increasing the energy intake from the FV decrease the non-FV energy intake rather than the total energy; Non-FV energy intake was lower in the group with high FV energy density than the group with low FV energy density ($p<0.0001$); increasing previous F2S years decreased both total and non-FV energy intake

Table 2.2 continued

Reference	Study purpose	Participants	Days of data collection	Rating scale	Outcome measurements	Key Results
Hubbard et al. (2014) [94]	To test whether a Smarter Lunchroom intervention could have positive impacts on the dietary patterns among adolescents and young adults with disabilities	students aged of 11-22 years (n=43) with intellectual and developmental disabilities from 1 residential school	5 consecutive days both at baseline and follow-up	Quarter system [f]	The percentage amounts (grams and servings) of food selection, waste, and consumption (compared to reference portion for weight and NDSR standard recipes for servings [g]);	Whole grains: a mean of 0.44 and 0.38 servings increased in selection and consumption, respectively Refined grains: a mean of 0.33 and 0.31 servings decreased in selection and consumption, respectively. Fruit: a mean of 0.18 servings increased in consumption; a mean of 9.4% decreased in waste Vegetable: a mean of 9% decreased in waste Total energy and weight of selection and consumption were not unchanged
Taylor et al. (2014) [95]	To assess the validity and reliability of digital imaging (DI) and DI with observation (DI+O) to determine FV consumption through comparing to measured weight	3-5th grade students (n=958) from 2 elementary schools	4 days per school	6-point scale [h]	The percentage, and amounts (gram) of food selection, waste, and consumption; Initial weight of food items on sample tray; Weight of food items left on individual tray;	DI: percent agreement was 96% and ICC was 0.92; Pearson correlation with weight of FV consumption was high (r=0.96, p<0.001) DI+O: Pearson correlation with weight of FV consumption was high (r=0.98, p<0.001). The limits of agreement for individual tray FV consumption was large

Table 2.2 continued

Reference	Study purpose	Participants	Days of data collection	Rating scale	Outcome measurements	Key Results
Bontrager Yoder et al. (2015) [96]	To identify the factors influencing FV waste in schools in Wisconsin participating F2S program	3-5^{th} grade students (n=1877) from 11 elementary schools	No specific days information; Data collection occurred within 2 weeks in Fall &Spring in 2010, 2011; Spring in 2012, 2013	Quarter system [f]	The percentage, and amounts (cups) of food selection, waste, and consumption;	Cooking style: cooked fruit wasted less than raw, but cooked vegetable wasted more than raw; Source: locally sourced and salad bar items wasted more than conventionally sourced and main menu items, respectively; FV as entrée components wasted more than as side dish or toppings; Previous F2S years: decreased wastes HHFKA implementation: no significant changes
Monlezun et al. (2015) [97]	To evaluate the impacts of hands-cooking and gardening classes (ESY) [i] on the eating patterns among elementary and middle school students	K-5^{th} grade students from 1 elementary school and 6-8^{th} grade students from 1 middle school (n= 479 in total)	5 days	10% increments [a]	The percentage, amounts, energy (kcal), and macro- and micro-nutrients information of food selection, waste, and consumption	8^{th} grade students with more ESY exposure consumed less saturated fat, less total fat, more fruit; near double the percentage of students with the sodium intake less than 1000 mg.

Table 2.2 continued

Reference	Study purpose	Participants	Days of data collection	Rating scale	Outcome measurements	Key Results
Alaimo et al. (2015) [98]	To evaluate the effects of FIT project on children's nutrition outcomes and to report the project implementation	3-5th grade students from 6 elementary schools (4 are intervention schools and 2 are control schools)	3 consecutive days per intervention school both at year 1 and year 2: 3 consecutive days per control school at year 2	Quarter system [f]	The percentage, amounts of food selection and consumption; Self-reported dietary intake (from survey); Knowledge, attitudes, and beliefs (from survey)	Plate waste: fruit consumption increased at year 2 in intervention schools but decreased in control schools ($p<0.05$). Surveys: the frequency of whole grain bread, fruit, and vegetable consumption increased at year 2 ($p<0.05$). Process: implementation of most intervention components increased at year 2.
Taylor et al. (2017) [99]	To assess the feasibility and inter-rater reliability of photo-based visual estimation method to determine food selection and consumption in packed lunches	Study 1: 4-6th grade students (n=35) from 1 elementary school Study 2: 4-6th grade students (n=315) from 3 elementary schools	5 consecutive days both in Study 1 and 2	10% increments [a]	The percentage, and amounts of food selection, waste, and consumption; Written description, food brands, and portions size of the food;	Feasibility: more than 10% of photo images cannot be used in Study 1. In Study 2: 7% of lunch missed the images Inter-rater reliability: food types selected, amounts of selection and consumption in the eight food categories have high agreement (weighted κ = 0.68 to 0.97 for packed lunches, 0.74 to 0.97 for school lunches); lowest reliability for estimating condiments and meats/meat alternatives in packed lunches

Table 2.2 Continued

Note:
[a] 10% increments: estimate in the unit of 10% , from 0-100% (such as 20%, 70%).
[b] CDI: child depression inventory
[c] RSES : Rosenberg self-esteem scale
[d] CNR: Child Nutrition and WIC Reauthorization Act of 2004
[e] HEI: Health eating index
[f] Quarter system: estimates wastes in the unit of ¼, as 0% , 25%, 50%, 75%, and 100%.
[g] NDSR: Nutrition Data System for Research
[h] 6 point scale: estimation in one of the following categories none = 0%, taste=10%, some=25%, half=50%, most=75%, and all=100%
[i] ESY: Edible Schoolyard

visual estimation method is assessed by comparing to a gold standard method such as the weighing method or DLW method. However, in this study, Pearson correlations between the visual estimations and BMI percentiles, or between the visual estimations and depressed mood and self-esteem was calculated to test the validity.[91] Results demonstrated the visual estimations had a significant correlation with BMI percentiles ($p<0.01$) which supported the convergent validity, but non-significant correlations with depressed mood and self-esteem ($p=0.45$ and 0.22, respectively) which supported the discriminant validity.[91]

Since the pictures are taken before and after eating, one concern related to the validity of photo-based visual estimations is that behaviors occurring during lunch cannot be captured by photos, such as sharing or trading food and returning for second servings, which may increase the bias of the estimations. So some researchers proposed to incorporate observations during lunchtime into the standard photo-based method to increase its validity.[91,92] However, is this practice necessary? What is the extent to which such behaviors influence the students' dietary patterns? The study from Taylor et al. (2014) provided some insights.[95] The validities of the standard photo-based method and the combination method incorporating observations for measuring fruit and vegetable consumption were compared with the weighing method.[95] Pearson correlations indicated the fruit and vegetable consumption estimated by either the standard method or the combination method was highly correlated to the weighing method ($r>0.95$ for both). The amounts of vegetable consumption estimated by the standard photo-based method was even more accurate than the estimations by the combination method.[95] This study indicated the standard photo-based method was valid, and incorporating observations during mealtime may not provide a significant influence on improving the estimation accuracy.

Students and their parents have the option to have the lunch provided by the NSLP, or packed their own lunch from home. Using a valid and reliable method to assess the dietary intake from packed lunches is important for us to understand children's overall nutrition status. The photo-based visual estimation method has been shown to be valid and reliable to assess the dietary intake from lunches provided by the NSLP. Will this method also be feasible and reliable to estimate packed lunches? Some insights could be obtained from a study from Taylor et.al. (2017).[99] The weighted κ coefficients from 0.68 to 0.97 for estimating selected food types and the amounts of food selection and consumption in packed lunches indicated high reliability, similarly to the weighted κ coefficients from 0.74 to 0.97 for school lunches in the same setting [99]. The time required to take photos and the percentage of missing data were used to test its feasibility. The results showed the most frequent reason (61%) causing the food to not be identified or estimated was the limited visibility of contents due to packing.[99] The missing data percentage decreased when multiple plate waste photos were taken.[99]

Two studies, Martin et.al. (2010) and Smith and Cunningham-Sabo (2013), evaluated the selection and consumption patterns in school lunches, and compared students' nutrient intake with the recommendations.[92,93] Two nutrition recommendations were used as the reference values in both studies, the *SMI standards* and the *2010 IOM recommendations*. Although the names of the standards used in Smith and Cunningham-Sabo's study were not the same as in Martin's, after comparing each reference values used in both studies, we found the *2004 CNR meal guidelines* and *HHFKA meal guidelines* stated in Smith and Cunningham-Sabo's study were respondent to the *SMI standards* and the *2010 IOM recommendations,* respectively. The percentages of food selection, waste, and consumption were estimated, and the amounts of food items and energy/nutrient intake were calculated using the values for reference portions. The results regarding the percentages of students who met specific nutrient recommendations were quite different in these two studies.[92,93] When compared to the *SMI standards*, the percentages of students meeting the energy and iron recommendations were much higher in Martin's study, but for total fat and saturated fat recommendations, the percentages were much higher in Smith and Cunningham-Sabo's study.[92,93] When compared to the *2010 IOM recommendations* , the percentages that met the total fat and saturated fat recommendations stayed higher in Smith and Cunningham-Sabo's study, but Martin reported a higher percentage for meeting calcium recommendations.[92,93] Several reasons might contribute to the differences between the two studies. First, the procedure of taking pictures may influence the accuracy of estimations. In Smith and Cunningham-Sabo's study, the before-eating photos were not taken for each student, instead, five servings of each pre-portioned item were photographed and used as the reference to compare with the after-eating photos.[93] Although the study indicated little variations were found among the initial portion sizes for most of the menu items, it could still be possible that some trays may have a large variation resulting in increased bias in the estimations. Second, the intake of energy and nutrients were compared with the recommendations in Smith and Cunningham-Sabo's study. However, it was the selection, rather than the intake, that was compared in Martin's study.[92,93] According to the *2010 IOM recommendations,* the nutrient recommendations were used to provide a scientific basis for setting standards for menu planning, so the results from Martin's study in which the selection values were compared might be more convincing and appropriate. Thirdly, the characteristics of the study participants were quite different, such as the predominant population was white in Smith and Cunningham-Sabo's study, but in Martin's study, the population was predominantly African American.[92,93]

School-based programs or interventions may have potential positive impacts on students' dietary behaviors and nutrient intake. Five studies summarized in Table 2 evaluated effects of various programs/interventions.[12,89,94,97,98] The practices implemented include: promoting the environmental modifications in school cafeterias (such as the LA Health and Wise Mind projects and Smarter Lunchroom interventions),[12,111] increasing the fruit and vegetable accessibility and exposure (such as the Farm to School program and Edible Schoolyard),[89, 97] connecting school, community, and social market together (such as the multi-component FIT project).[98] Positive impacts on dietary patterns or nutrient intake were reported in all studies, and the improvements of fruit and vegetable selection or consumption were shown in four out of the five articles.[89,94,97,98] In addition, decreased intake of energy from total fat and saturated fat, increased intake of whole grains, and decreased intake of refined grains were reported.[12,97,98]

In addition to programs and interventions, some other factors may also have an influence on fruit and vegetable consumption. A study from Bontrager Yoder and colleague (2015) estimated the percentage and amounts of fruit and vegetable selection and waste.[96] Results showed the type of cooking (raw VS cooked), source of items (locally sourced VS conventionally sourced), and meal component (part of an entrée VS side dish or toppings) could have a significant influence on fruit/vegetable waste.[96] However, even the same factor may influence the waste of fruit/vegetable differently.[96] Cooked fruits were wasted more than raw fruits ($p<0.05$), however, cooked vegetables were wasted less than raw vegetables ($p<0.05$).[96] The findings from this study could help schools for their menu planning, or for implementing different practices and strategies to improve fruit or vegetable consumption, as well as decrease the waste.

Limitations and Research Gaps Regarding the Photo-based Visual Estimation Method

Rating scales

Various rating scales have been used in photo-based visual estimations to determine the food waste or consumption, such as the 10%-increments, Quarter system, 6-point scale, and Third system. Williamson and colleague (2002) developed the photo-based visual estimation method using the scale of 10%-increments, which estimates the food waste in the unit of 10%.[88] The validity and reliability were then assessed by this research team through comparing to the weighing method or DLW method in various populations and settings.[82,85,91] Many studies used their protocol to conduct the visual estimations.[12,93,99] The Quarter system, as indicated by its name, estimates the food waste by quarter(s) and is another commonly used scale in visual estimations. Two studies from Hanks et al. (2014) and Getts et al. (2017) showed the high inter-rater reliability and high accuracy of the Quarter system by comparing to measured weights.[87,100] When using the 6-point scale, the food waste was estimated to the nearest category from the following: 0--none or less than 6%; 1--25%; 2--50%; 3--75%; 4--90%; 5--94% or more. This scale was developed by Comstock in 1981,[73] and now has been applied in various studies conducting visual estimations.[57,86,95,101]

The literature regarding the use of different rating scales can be confusing, and even using the same scale, misunderstandings are common. For example, the Third system was used in two studies, but the interpretations of this rating system were different.[73,102] In the study by Acredolo and Pick (1975), the consumption, rather than the waste, was estimated to fall into one of the following categories: 0--nothing eaten; 1--one bite eaten; 2--more than one bite but not whole portion eaten; 3--whole portion eaten.[102] However, in another study, food waste was estimated using third(s).[73]

Although the validity and reliability of different rating scales were tested in different studies separately, few studies compared the accuracies of these rating scales in the same setting or compared them to one "gold standard" method. In the study from Hanks et al. (2014), The Quarter system, Half system, and the 10%-increment scale were assessed for reliability and accuracy when compared to the weighing method.[87] However, two types of visual estimations were also adopted in this study: the Quarter system and Half system were used in the on-site estimation method but the 10%-increment scale was used in the photo-based method. The differences of accuracies and reliabilities could be related to the rating scales, but may also be related to the type of visual estimations.

To better provide guidance for selecting an appropriate rating scale used in different settings or populations, future research comparing the various rating scales is needed with improved study design.

Factors influencing people's perception of food portion size

Various factors, including gender, age, BMI, participants' major background/occupation, the type of food/meal, portion size served, energy density, and appetite status, have been shown to significantly influence the accuracy of portion size estimations.

Gender needs to be considered when analyzing dietary assessment data, because the accuracy of portion size estimations differs significantly between males and females. Generally, females tend to estimate food portions more accurately than males, which was supported by the findings from two studies by Almiron-Roig et al. (2013) and Yuhas et al. (1989).[103,104] Nelson and colleague conducted two studies (1994 &1996) to explore the influence of various factors on people's perception of food portion size.[105,106] In the first study, 24 male and 27 female participants were asked to estimate the amount of six food items each with six portion sizes by comparing to reference photos as an aid.[105] The results indicated males underestimated the food portions while females tended to overestimate.[105] In a later study, they expanded the experimental scope involving 136 volunteers to participate.[106] Although the study procedure and method were similar as in the first study, the results were different: males overestimated more than females overall, especially for foods with small portion sizes ($p<0.001$).[106]

Another important finding from this study was that the older adults aged 65 years or older were found to overestimate the portions more often than the younger adults.[106] However, this finding was contradictory with the results from the study by Timon et al. (2017) [107]. In Timon's study, 40 older adults aged 65 years or older and 41 younger adults aged 18 to 40 years were asked to estimate portion sizes of foods from a buffet style set- up using either a traditional method or computer-based estimation aids.[107] The results demonstrated there was no significant difference between older and younger adults in their abilities to estimate portion size.[107] Twenty-five nutritionists also participated in this study, and their smaller range of ratio of visual estimations to actual weight showed the nutritionists had less variability in portion size estimations than older and younger adults.[107] However, one limitation should be noted for this study: the nutritionists conducted photo-based visual estimations, but the younger and older adults performed on-site direct visual estimations. The comparisons between the two groups (nutritionists VS older& younger adults without nutrition profession backgrounds) were not very convincing without rigidly controlling the variables.[107]

People with obesity were found to under-report their dietary intake in self-reported dietary assessments.[108] An 8% underestimation of portion size was found in people with a BMI of 30 kg/m^2 or larger when visually estimating portion size.[105] In a second study (1996) from this same research team, they not only evaluated the accuracy of portion size estimations, but also calculated energy and fat contents based on the portion size estimations.[106] This study showed the energy and fat contents were underestimated by 2-5% in people with a BMI of 30 kg/m^2 or larger, but were overestimated by 5-10% in people with a BMI of 25 kg/m^2 or less.[106]

Appetite status may influence visual estimations of food portion size as well. Two articles from the same study conducted by Brogden and Almiron-Roig (2010 &2011) were related to study participant's appetite level.[109,110] Twenty-seven men participated in four laboratory sessions to estimate the portions of eight foods and beverages, and two of the four sessions were conducted after an overnight fast (hunger condition) and the other two sessions were after breakfast (full condition).[109,110] The expected satiety power after consuming the estimated food were also rated in one hunger and one full condition.[110] Although the estimated portions were significantly smaller for all food items except bananas, regardless of the appetite status ($p<0.01$), the participants underestimated to a greater extent in the hunger condition compared to the full condition ($p<0.01$).[109] They also found the underestimations of portion size were correlated with the higher excpeted satiety ratings. In other words, if people perceived the estimated food could make them feel more satiated after consuming, they tended to underestimate the portions.[110] Another study, which asked 55 female students to indicate their usual portion size before and after lunch, showed the influence of appetite status might vary by food.[111] For fruit salad, the influence of appetite status was very small, however, it was largest for rice, then cheesecake, and then chips.[111] In addition to appetite status, the experience of visual exposures may also influence people' perception of food portion size. People with visual exposures to large portions of spaghetti/snacks before the visual estimations tended to have a larger perception of "normal portion size" compared to those exposed to small portions.[112]

The influences from food-related factors could not be ignored when conducting visual estimations. Yuhas et al. (1989) reported the accuracy of estimating portion size was highest in solid food, followed by liquid, with amorphous food being the lowest.[104] However, results were different in the study by Hernandez and colleague (2006): the estimation error (mean ± standard error of the mean) for solid food, amorphous food, and liquid was 8.3% ± 2.3 %, -10% ± 2.7% , 19% ± 5%, respectively.[113] The different results observed in these two studies might be due to the differences in study purpose, design, setting, and participants. Yuhas's study was to test the effects of a training on enhancing the accuracy of portion size estimations, and the participants were students in a large nutrition course.[104] However, in Hernandez's study, the influence of computer-based portion anchors on decreasing estimation errors was assessed, and the participants were middle-aged (and not students studying nutrition).[113] As discussed earlier, the age and major background provides a potential influence on estimation results, which may partially explain the differences observed in the two studies. Hernandez's study also mentioned an inverse correlation between amounts of food served and the magnitude of estimation error, which was supported by the study from Gittelsohn and colleague (1994).[76,113] It showed the estimates for food with small quantities (less than 20 grams) were less accurate.[76] Nelson's studies provided further explanations for the influence of food quantities on visual estimations: the overestimations occurred more in small portions but underestimations were more in large portion sizes.[105,106] Gittelsohn mentioned in his study (1994) that food with high volume but light weight tended to be estimated less accurate, indicating the influence of food density on visual estimations.[76] Japur and Diez-Garcia reported in their study (2010) a positive relationship was found between the accuracy of estimations and the energy density of food ($r=0.82$, $p<0.001$).[114]

Taken together, various personal-related, psychological, and food-related factors have been studied for their influence on food portion size estimations. However, conflicting results were found among different studies due to their variations in study purpose, design, method, setting, and participants. However, few studies examined the influence of such factors on different rating scales in the photo-based visual estimation method. To have a better understanding of people's perception of food portions and to improve the estimation accuracy, studies exploring the influence of various factors in the context of considering the rating scales are needed.

Summary of Part III

Valid and reliable dietary assessment methods play a significant role in understanding the dietary intake and eating patterns in children and adolescents. Self-reported dietary assessment methods and the weighing method are commonly used. Due to the higher flexibility, cost-effectiveness, and easy-implementation, visual estimation methods, especially the photo-based method, has been used more in recent studies. After summarizing the school plate waste studies using photo-based visual estimations to determine the food selection, waste, and consumption during school lunch, some limitations and research gaps were found. Further studies are needed to compare the accuracies of different rating scales and to explore the influence of various factors on photo-based visual estimations when selecting a specific rating scale.

References

1. Association AD, (ADA). Position of the American Dietetic Association: individual-, family-, school-, and community-based interventions for pediatric overweight. *J Am Diet Assoc*. 2006;106(6):925-945. doi:10.1016/j.jada.2006.03.001.

2. Hoelscher DM, Kirk S, Ritchie L, Cunningham-Sabo L. Position of the Academy of Nutrition and Dietetics: Interventions for the Prevention and Treatment of Pediatric Overweight and Obesity. *J Acad Nutr Diet*. 2013;113(10):1375-1394. doi:10.1016/j.jand.2013.08.004.

3. Hills AP, King NA, Byrne NM. *Children, Obesity and Exercise : Prevention, Treatment, and Management of Childhood and Adolescent Obesity*. Routledge; 2007. https://www.routledge.com/Children-Obesity-and-Exercise-Prevention-Treatment-and-Management-of/Hills-King-Byrne-Bailey-ICSSPE/p/book/9780415408844. Accessed August 14, 2018.

4. Hodges EA. A primer on early childhood obesity and parental influence. *Pediatr Nurs*. 29(1):13-16. http://www.ncbi.nlm.nih.gov/pubmed/12630500. Accessed August 17, 2018.

5. Pate RR, Trost SG, Mullis R, Sallis JF, Wechsler H, Brown DR. Community Interventions to Promote Proper Nutrition and Physical Activity among Youth. *Prev Med (Baltim)*. 2000;31(2):S138-S149. doi:10.1006/PMED.2000.0632.

6. Yancey AK, Kumanyika SK, Ponce NA, et al. Population-based interventions engaging communities of color in healthy eating and active living: a review. *Prev Chronic Dis*. 2004;1(1):A09. http://www.ncbi.nlm.nih.gov/pubmed/15634371. Accessed August 17, 2018.

7. King AC. How to promote physical activity in a community: Research experiences from the US highlighting different community approaches. *Patient Educ Couns*. 1998. doi:10.1016/S0738-3991(98)00004-4.

8. Kriemler S, Meyer U, Martin E, van Sluijs EMF, Andersen LB, Martin BW. Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of reviews and systematic update. *Br J Sports Med*. 2011;45(11):923-930. doi:10.1136/bjsports-2011-090186.

9. Jago R, Baranowski T. Non-curricular approaches for increasing physical activity in youth: a review. *Prev Med (Baltim)*. 2004;39(1):157-163. doi:10.1016/j.ypmed.2004.01.014.

10. French SA, Stables G. Environmental interventions to promote vegetable and fruit consumption among youth in school settings. *Prev Med (Baltim)*. 2003;37(6):593-610. doi:10.1016/J.YPMED.2003.09.007.

11. Williamson DA, Champagne CM, Harsha DW, et al. Effect of an Environmental School-Based Obesity Prevention Program on Changes in Body Fat and Body Weight: A Randomized Trial. *Obesity*. 2012;20(8):1653-1661. doi:10.1038/oby.2012.60.

12. Williamson DA, Han H, Johnson WD, Martin CK, Newton RL. Modification of the school cafeteria environment can impact childhood nutrition. Results from the Wise Mind and LA Health studies. *Appetite*. 2013;61:77-84. doi:10.1016/j.appet.2012.11.002.

13. Ishdorj A, Crepinsek MK, Jensen HH. Children's Consumption of Fruits and Vegetables: Do School Environment and Policies Affect Choices at School and Away from School? *Appl Econ Perspect Policy*. 2013;35(2):341-359. doi:10.1093/aepp/ppt003.

14. Foster GD, Sherman S, Borradaile KE, et al. A Policy-Based School Intervention to Prevent Overweight and Obesity. *Pediatrics*. 2008;121(4):e794-e802. doi:10.1542/peds.2007-1365.

15. States Department of Agriculture U. Local School Wellness Policy Implementation Under the Healthy, Hunger-Free Kids Act of 2010. Final rule. *Fed Regist*. 2016;81(146):50151-50170.

16. Malina RM, Bouchard C, Bar-Or O. *Growth, Maturation, and Physical Activity*. Human Kinetics; 2004. https://books.google.com/books/about/Growth_Maturation_and_Physical_Activity.html?id=VqFcFsykj6EC. Accessed August 17, 2018.

17. Smethers AD, Rolls BJ. Dietary Management of Obesity Cornerstones of Healthy Eating Patterns. 2018. doi:10.1016/j.mcna.2017.08.009.

18. Perry CL, Bishop DB, Taylor GL, et al. A Randomized School Trial of Environmental Strategies to Encourage Fruit and Vegetable Consumption among Children. *Heal Educ Behav*. 2004;31(1):65-76. doi:10.1177/1090198103255530.

19. Cullen KW, Chen T-A, Dave JM, Jensen H. Differential Improvements in Student Fruit and Vegetable Selection and Consumption in Response to the New National School Lunch Program Regulations: A Pilot Study. *J Acad Nutr Diet*. 2015;115:743-750. doi:10.1016/j.jand.2014.10.021.

20. Swanson M, Branscum A, Nakayima PJ. *Promoting Consumption of Fruit in Elementary School Cafeterias. The Effects of Slicing Apples and Oranges*. Vol 53.; 2009. doi:10.1016/j.appet.2009.07.015.

21. Fox MK, Condon E. *School Nutrition Dietary Assessment Study-IV Summary of Findings*.; 2012. www.fns.usda.gov/cnd. Accessed August 5, 2018.

22. Farris AR, Misyak S, Duffey KJ, et al. Nutritional Comparison of Packed and School Lunches in Pre-Kindergarten and Kindergarten Children Following the Implementation of the 2012–2013 National School Lunch Program Standards. *J Nutr Educ Behav*. 2014;46(6):621-626. doi:10.1016/J.JNEB.2014.07.007.

23. Rees GA, Richards CJ, Gregory J. Food and nutrient intakes of primary school children: a comparison of school meals and packed lunches. *J Hum Nutr Diet*. 2008;21(5):420-427. doi:10.1111/j.1365-277X.2008.00885.x.

24. Booth FW, Chakravarthy M V., Gordon SE, Spangenburg EE. Waging war on physical inactivity: using modern molecular ammunition against an ancient enemy. *J Appl Physiol*. 2002;93(1):3-30. doi:10.1152/japplphysiol.00073.2002.

25. Dunn AL, Trivedi MH, O'Neal HA. Physical activity dose-response effects on outcomes of depression and anxiety. *Med Sci Sports Exerc*. 2001;33(6 Suppl):S587-97-10. http://www.ncbi.nlm.nih.gov/pubmed/11427783. Accessed August 19, 2018.

26. Long SJ, Hart K, Morgan LM. The ability of habitual exercise to influence appetite and food intake in response to high- and low-energy preloads in man. *Br J Nutr*. 2002;87(5):517-523. doi:10.1079/BJNBJN2002560.

27. HHS. *2018 Physical Activity Guidelines Advisory Committee Scientific Report*.; 2018. https://health.gov/paguidelines/second-edition/report/pdf/PAG_Advisory_Committee_Report.pdf. Accessed August 20, 2018.

28. National Physical Activity Plan Alliance. *2016 UNITED STATES REPORT CARD ON PHYSICAL ACTIVITY FOR CHILDREN AND YOUTH*. http://www.physicalactivityplan.org/projects/PA/2016FINAL_PAReportCard_Summary.pdf. Accessed August 20, 2018.

29. Crawford D, Ball K. Behavioural determinants of the obesity epidemic. *Asia Pac J Clin Nutr*. 2002;11(s8):S718-S721. doi:10.1046/j.1440-6047.11.s8.14.x.

30. Robinson TN. Reducing Children's Television Viewing to Prevent Obesity. *JAMA*. 1999;282(16):1561. doi:10.1001/jama.282.16.1561.

31. American Academy of Pediatrics. American Academy of Pediatrics Announces New Recommendations for Children's Media Use. American Academy of Pediatrics website. https://www.aap.org/en-us/about-the-aap/aap-press-room/Pages/American-Academy-of-Pediatrics-Announces-New-Recommendations-for-Childrens-Media-Use.aspx. Published 2016. Accessed August 20, 2018.

32. Rogers VW, Hart PH, Motyka E, Rines EN, Vine J, Deatrick DA. Impact of Let's Go! 5-2-1-0: a community-based, multisetting childhood obesity prevention program. *J Pediatr Psychol*. 2013;38(9):1010-1020. doi:10.1093/jpepsy/jst057.

33. Rideout VJ, Ulla MA, Foehr G, Roberts DF. *A Kaiser Family Foundation Study GENERATION M 2 Media in the Lives of 8-to 18-Year-Olds*.; 2010. https://kaiserfamilyfoundation.files.wordpress.com/2013/04/8010.pdf. Accessed August 20, 2018.

34. Eisenmann JC, Gentile DA, Welk GJ, et al. SWITCH: rationale, design, and implementation of a community, school, and family-based intervention to modify behaviors related to childhood obesity. *BMC Public Health*. 2008;8(1):223. doi:10.1186/1471-2458-8-223.

35. Welk GJ, Chen S, Nam YH, Weber TE. A formative evaluation of the SWITCH® obesity prevention program: print versus online programming. *BMC Obes*. 2015;2(1):20. doi:10.1186/s40608-015-0049-1.

36. Gentile DA, Welk G, Eisenmann JC, et al. Evaluation of a multiple ecological level child obesity prevention program: Switch®what you Do, View, and Chew. *BMC Med*. 2009;7(1):49. doi:10.1186/1741-7015-7-49.

37. Blankenship KM, Friedman SR, Dworkin S, Mantell JE. Structural Interventions: Concepts, Challenges and Opportunities for Research. *J Urban Heal*. 2006;83(1):59-72. doi:10.1007/s11524-005-9007-4.

38. Schwartz MB. The influence of a verbal prompt on school lunch fruit consumption: a pilot study. *Int J Behav Nutr Phys Act*. doi:10.1186/1479.

39. Mansfield JL, Savaiano DA. Effect of school wellness policies and the Healthy, Hunger-Free Kids Act on food-consumption behaviors of students, 2006–2016: a systematic review. *Nutr Rev*. 2017;75(7):533-552. doi:10.1093/nutrit/nux020.

40. Vazou S, Skrade MAB. Intervention integrating physical activity with math: Math performance, perceived competence, and need satisfaction. *Int J Sport Exerc Psychol*. 2017;15(5):508-522. doi:10.1080/1612197X.2016.1164226.

41. Chen S, Zhu X, Welk GJ, Kim Y, Lee J, Meier NF. Using Sensewear armband and diet journal to promote adolescents' energy balance knowledge and motivation. *J Sport Heal Sci*. 2014;3(4):326-332. doi:10.1016/J.JSHS.2013.07.003.

42. Ravitz J, Hoadley C. Supporting change and scholarship through review of online resources in professional development settings. *Br J Educ Technol*. 2005;36(6):957-974. doi:10.1111/j.1467-8535.2005.00567.x.

43. So H-J, Lossman H, Lim W-Y, Jacobson MJ. Designing an online video based platform for teacher learning in Singapore. *Australas J Educ Technol*. 2009;25(3). doi:10.14742/ajet.1144.

44. States Department of Agriculture U. *THE NATIONAL SCHOOL LUNCH PROGRAM*. http://www.fns.usda.gov/tn/team-nutrition. Accessed August 3, 2018.

45. Gordon AR, Cohen R, Crepinsek MK, Fox MK, Hall J, Zeidman E. The Third School Nutrition Dietary Assessment Study: Background and Study Design. *J Am Diet Assoc*. 2009;109(2):S20-S30. doi:10.1016/j.jada.2008.10.057.

46. Stallings VA, Suitor CW, Taylor CL. *School Meals*.; 2010. doi:10.17226/12751.

47. Abraham S, Daft L, Chattopadhyay M, et al. *THE SCHOOL MEALS INITIATIVE IMPLEMENTATION STUDY FIRST YEAR REPORT*.; 2000. https://fns-prod.azureedge.net/sites/default/files/SMIYear1.pdf. Accessed August 31, 2018.

48. Gleason P, Suitor C. Children's Diets in the Mid-1990s: Dietary Intake and Its Relationship with School Meal Participation. *Math Policy Res Reports*. https://ideas.repec.org/p/mpr/mprres/8db693ba4d8640ec87d978a342a6ec5d.html. Accessed August 8, 2018.

49. Burghardt JA, Devaney BL, Gordon AR. The School Nutrition Dietary Assessment Study: summary and discussion. *Am J Clin Nutr*. 1995;61(1):252S-257S. doi:10.1093/ajcn/61.1.252S.

50. Fox MK, Crepinsek MK, Connor P, Battaglia M. *School Nutrition Dietary Assessment Study-II Final Report*.; 2001. http://www.fns.usda.gov/oane. Accessed September 2, 2018.

51. Story M. The Third School Nutrition Dietary Assessment Study: Findings and Policy Implications for Improving the Health of US Children. *J Am Diet Assoc*. 2009;109(2):S7-S13. doi:10.1016/j.jada.2008.11.005.

52. States U. *School Nutrition Dietary Assessment Study-III Summary of Findings*.; 2007. www.fns.usda.gov/cnd/. Accessed August 5, 2018.

53. Cohen JFW, Richardson S, Parker E, Catalano PJ, Rimm EB. Impact of the new U.S. Department of Agriculture school meal standards on food selection, consumption, and waste. *Am J Prev Med*. 2014;46(4):388-394. doi:10.1016/j.amepre.2013.11.013.

54. Schwartz MB, Henderson KE, Read M, Danna N, Ickovics JR. New School Meal Regulations Increase Fruit Consumption and Do Not Increase Total Plate Waste. doi:10.1089/chi.2015.0019.

55. Byker CJ, Farris AR, Marcenelle M, Davis GC, Serrano EL. Food Waste in a School Nutrition Program After Implementation of New Lunch Program Guidelines. *J Nutr Educ Behav*. 2014;46(5):406-411. doi:10.1016/j.jneb.2014.03.009.

56. Cullen KW, Chen T-A, Dave JM. Changes in foods selected and consumed after implementation of the new National School Lunch Program meal patterns in southeast Texas. *Prev Med reports*. 2015;2:440-443. doi:10.1016/j.pmedr.2015.05.007.

57. Amin SA, Yon BA, Taylor JC, Johnson RK. Impact of the National School Lunch Program on Fruit and Vegetable Selection in Northeastern Elementary Schoolchildren, 2012-2013. *Public Health Rep*. 2015;130(5):453-457. doi:10.1177/003335491513000508.

58. Johnson DB, Podrabsky M, Rocha A, Otten JJ. Effect of the Healthy Hunger-Free Kids Act on the Nutritional Quality of Meals Selected by Students and School Lunch Participation Rates. *JAMA Pediatr*. 2016;170(1):e153918. doi:10.1001/jamapediatrics.2015.3918.

59. Adams MA, Bruening M, Ohri-Vachaspati P. Use of Salad Bars in Schools to Increase Fruit and Vegetable Consumption: Where's the Evidence? *J Acad Nutr Diet*. 2015;115(8):1233-1236. doi:10.1016/j.jand.2015.02.010.

60. Adams MA, Pelletier RL, Zive MM, Sallis JF. Salad Bars and Fruit and Vegetable Consumption in Elementary Schools: A Plate Waste Study. *J Am Diet Assoc*. 2005;105(11):1789-1792. doi:10.1016/j.jada.2005.08.013.

61. Adams MA, Bruening M, Ohri-Vachaspati P, Hurley JC. Location of School Lunch Salad Bars and Fruit and Vegetable Consumption in Middle Schools: A Cross-Sectional Plate Waste Study. *J Acad Nutr Diet*. 2016;116(3):407-416. doi:10.1016/j.jand.2015.10.011.

62. Hakim SM, Meissen G. Increasing Consumption of Fruits and Vegetables in the School Cafeteria: The Influence of Active Choice. *J Health Care Poor Underserved*. 2013;24(2A):145-157. doi:10.1353/hpu.2013.0109.

63. Wansink B, Just DR, Hanks AS, Smith LE. Pre-Sliced Fruit in School Cafeterias. *Am J Prev Med*. 2013;44(5):477-480. doi:10.1016/j.amepre.2013.02.003.

64. Wansink B, Just DR, Payne CR, Klinger MZ. Attractive names sustain increased vegetable intake in schools. *Prev Med (Baltim)*. 2012;55(4):330-332. doi:10.1016/j.ypmed.2012.07.012.

65. Lakkakula A, Geaghan JP, Wong W-P, Zanovec M, Pierce SH, Tuuri G. *A Cafeteria-Based Tasting Program Increased Liking of Fruits and Vegetables by Lower, Middle and Upper Elementary School-Age Children*. Vol 57.; 2011. doi:10.1016/j.appet.2011.04.010.

66. Bica LA, Jamelske EM, Lagorio CH. *Increasing Fruit and Vegetable Consumption During Elementary School Snack Periods Using Incentives, Prompting and Role Modeling*. http://schoolnutrition.org/uploadedFiles/5_News_and_Publications/4_The_Journal_of_Child_Nutrition_and_Management/Fall_2016/IncreasingFruitandVegetableConsumptionDuringElementary.pdf. Accessed September 4, 2018.

67. Mcpherson RS, Hoelscher DM, Alexander M, Scanlon KS, Serdula MK. Dietary Assessment Methods among School-Aged Children: Validity and Reliability. *Prev Med (Baltim)*. 2000;31:11-33. doi:10.1006.

68. Thompson FE, Subar AF. Nutrition in the Prevention and Treatment of Disease. 2017. doi:10.1016/B978-0-12-802928-2.00001-1.

69. Moshfegh AJ, Rhodes DG, Baer DJ, et al. The US Department of Agriculture Automated Multiple-Pass Method reduces bias in the collection of energy intakes. *Am J Clin Nutr*. 2008;88(2):324-332. doi:10.1093/ajcn/88.2.324.

70. Burke BS, Stuart HC. A method of diet analysis. *J Pediatr*. 1938;12(4):493-503. doi:10.1016/S0022-3476(38)80088-3.

71. Livingstone MBE, Robson PJ. Measurement of dietary intake in children. *Proc Nutr Soc*. 2000;59(2):279-293. doi:10.1017/S0029665100000318.

72. Burrows TL, Martin RJ, Collins CE. A Systematic Review of the Validity of Dietary Assessment Methods in Children when Compared with the Method of Doubly Labeled Water. *J Am Diet Assoc*. 2010;110(10):1501-1510. doi:10.1016/J.JADA.2010.07.008.

73. Comstock EM, St Pierre RG, Mackiernan YD. Measuring individual plate waste in school lunches. Visual estimation and children's ratings vs. actual weighing of plate waste. *J Am Diet Assoc*. 1981;79(3):290-296. http://www.ncbi.nlm.nih.gov/pubmed/7264115. Accessed January 15, 2018.

74. Byker Shanks C, Banna J, Serrano EL. Food Waste in the National School Lunch Program 1978-2015: A Systematic Review. *J Acad Nutr Diet*. 2017;117(11):1792-1807. doi:10.1016/j.jand.2017.06.008.

75. Friedman B, Hurd-Crixell SL. Nutrient Intake of Children Eating School Breakfast. *J Am Diet Assoc*. 1999;99(2):219-221. doi:10.1016/S0002-8223(99)00052-8.

76. Gittelsohn J, Shankar AV., Pokhrel RP, West KP. Accuracy of estimating food intake by observation. *J Am Diet Assoc*. 1994;94(11):1273-1277. doi:10.1016/0002-8223(94)92459-7.

77. Martin CK, Nicklas T, Gunturk B, Correa JB, Allen HR, Champagne C. Measuring food intake with digital photography. *J Hum Nutr Diet*. 2014;27(s1):72-81. doi:10.1111/jhn.12014.

78. Williamson DA, Allen HR, Martin PD, Alfonso AJ, Gerald B, Hunt A. Comparison of digital photography to weighed and visual estimation of portion sizes. *J Am Diet Assoc*. 2003;103(9):1139-1145. doi:10.1016/S0002-8223(03)00974-X.

79. Williamson DA, Copeland AL, Anton SD, et al. Wise Mind Project: A School-based Environmental Approach for Preventing Weight Gain in Children*. *Obesity*. 2007;15(4):906-917. doi:10.1038/oby.2007.597.

80. Williamson DA, Champagne CM, Harsha D, et al. Louisiana (LA) Health: Design and methods for a childhood obesity prevention program in rural schools. *Contemp Clin Trials*. 2008;29(5):783-795. doi:10.1016/j.cct.2008.03.004.

81. Martin CK, Han H, Coulon SM, Allen HR, Champagne CM, Anton SD. A novel method to remotely measure food intake of free-living individuals in real time: the remote food photography method. *Br J Nutr*. 2009;101(3):446. doi:10.1017/S0007114508027438.

82. Nicklas T, Saab R, Islam NG, et al. Validity of the Remote Food Photography Method Against Doubly Labeled Water Among Minority Preschoolers. *Obesity*. 2017;25(9):1633-1638. doi:10.1002/oby.21931.

83. Olafsdottir AS, Hörnell A, Hedelin M, Waling M, Gunnarsdottir I, Olsson C. Development and Validation of a Photographic Method to Use for Dietary Assessment in School Settings. Portero-Otin M, ed. *PLoS One*. 2016;11(10):e0163970. doi:10.1371/journal.pone.0163970.

84. Liz Martins M, Cunha LM, Rodrigues SSP, Rocha A. Determination of plate waste in primary school lunches by weighing and visual estimation methods: A validation study. *Waste Manag*. 2014;34(8):1362-1368. doi:10.1016/J.WASMAN.2014.03.020.

85. Williamson DA, Allen HR, Martin PD, Alfonso A, Gerald B, Hunt A. Digital photography: A new method for estimating food intake in cafeteria settings. *Eat Weight Disord - Stud Anorexia, Bulim Obes*. 2004;9(1):24-28. doi:10.1007/BF03325041.

86. Parent M, Niezgoda H, Keller HH, Chambers LW, Daly S. Comparison of Visual Estimation Methods for Regular and Modified Textures: Real-Time vs Digital Imaging. *JAND*. 2012;112:1636-1641. doi:10.1016/j.jand.2012.06.367.

87. Hanks AS, Wansink B, Just DR. Reliability and accuracy of real-time visualization techniques for measuring school cafeteria tray waste: validating the quarter-waste method. *J Acad Nutr Diet*. 2014;114(3):470-474. doi:10.1016/j.jand.2013.08.013.

88. Williamson DA, Pamela ;, Martin D, et al. *Changes in Food Intake and Body Weight Associated with Basic Combat Training*. Vol 167.; 2002. https://academic.oup.com/milmed/article-abstract/167/3/248/4819905. Accessed September 13, 2018.

89. Bontrager Yoder AB, Liebhart JL, McCarty DJ, et al. Farm to Elementary School Programming Increases Access to Fruits and Vegetables and Increases Their Consumption Among Those With Low Intake. *J Nutr Educ Behav*. 2014;46(5):341-349. doi:10.1016/J.JNEB.2014.04.297.

90. Yoder ABB, Schoeller DA. Fruits and Vegetables Displace, But Do Not Decrease, Total Energy in School Lunches. *Child Obes*. 2014;10(4):357. doi:10.1089/CHI.2014.0017.

91. Martin CK, Newton RL, Anton SD, et al. Measurement of children's food intake with digital photography and the effects of second servings upon food intake. *Eat Behav*. 2007;8(2):148-156. doi:10.1016/j.eatbeh.2006.03.003.

92. Martin CK, Thomson JL, LeBlanc MM, et al. Children in School Cafeterias Select Foods Containing More Saturated Fat and Energy than the Institute of Medicine Recommendations1–4. *J Nutr*. 2010;140(9):1653-1660. doi:10.3945/jn.109.119131.

93. Smith SL, Cunningham-Sabo L. Food choice, plate waste and nutrient intake of elementary- and middle-school students participating in the US National School Lunch Program. *Public Health Nutr*. 2014;17(6):1255-1263. doi:10.1017/S1368980013001894.

94. Hubbard KL, Bandini LG, Folta SC, Wansink B, Eliasziw M, Must A. Impact of a Smarter Lunchroom intervention on food selection and consumption among adolescents and young adults with intellectual and developmental disabilities in a residential school setting. *Public Health Nutr*. 2015;18(2):361-371. doi:10.1017/S1368980014000305.

95. Taylor JC, Yon BA, Johnson RK. Reliability and Validity of Digital Imaging as a Measure of Schoolchildren's Fruit and Vegetable Consumption. *J Acad Nutr Diet*. 2014;114(9):1359-1366. doi:10.1016/j.jand.2014.02.029.

96. Bontrager Yoder AB, Foecke LL, Schoeller DA. Factors affecting fruit and vegetable school lunch waste in Wisconsin elementary schools participating in Farm to School programmes. *Public Health Nutr*. 2015;18(15):2855-2863. doi:10.1017/S1368980015000385.

97. Monlezun DJ, Ly D, Rolfsen M, et al. Digital photography assessment of 1,750 elementary and middle school student lunch meals demonstrates improved nutrition with increased exposure to hands-on cooking and gardening classes. *J Med Person*. 2015;13(2):129-134. doi:10.1007/s12682-014-0203-4.

98. Alaimo K, Carlson JJ, Pfeiffer KA, et al. Project FIT: A School, Community and Social Marketing Intervention Improves Healthy Eating Among Low-Income Elementary School Children. *J Community Health*. 2015;40(4):815-826. doi:10.1007/s10900-015-0005-5.

99. Taylor JC, Sutter C, Ontai LL, Nishina A, Zidenberg-Cherr S. Feasibility and reliability of digital imaging for estimating food selection and consumption from students' packed lunches. *Appetite*. 2018;120:196-204. doi:10.1016/j.appet.2017.08.037.

100. Getts KM, Quinn EL, Johnson DB, Otten JJ. Validity and Interrater Reliability of the Visual Quarter-Waste Method for Assessing Food Waste in Middle School and High School Cafeteria Settings. *J Acad Nutr Diet*. 2017;117(11):1816-1821. doi:10.1016/j.jand.2017.05.004.

101. Connors PL, Rozell SB. Using a visual plate waste study to monitor menu performance. *J Am Diet Assoc*. 2004;104(1):94-96. doi:10.1016/j.jada.2003.10.012.

102. Acredolo LP, Pick HL. OF A SCHOOL LUNCH PROGRAM'. @ *Psychol Reports*. 1975;37:33-34. http://journals.sagepub.com/doi/pdf/10.2466/pr0.1975.37.1.331. Accessed July 8, 2018.

103. Almiron-Roig E, Solis-Trapala I, Dodd J, Jebb SA. Estimating food portions. Influence of unit number, meal type and energy density. *Appetite*. 2013;71:95-103. doi:10.1016/j.appet.2013.07.012.

104. Yuhas JA, Bolland JE, Bolland TW. The impact of training, food type, gender, and container size on the estimation of food portion sizes. *J Am Diet Assoc*. 1989;89(10):1473-1477.

105. Nelson M, Atkinson M, Darbyshire S. Food Photography I: the perception of food portion size from photographs. *Br J Nutr*. 1994;72(5):649. doi:10.1079/BJN19940069.

106. Nelson M, Atkinson M, Darbyshire S. Food photography II: use of food photographs for estimating portion size and the nutrient content of meals. *Br J Nutr*. 1996;76(1):31. doi:10.1079/BJN19960007.

107. Timon CM, Cooper SE, Barker ME, et al. A comparison of food portion size estimation by older adults, young adults and nutritionists. *J Nutr Health Aging*. June 2017:1-7. doi:10.1007/s12603-017-0937-9.

108. Collins CE, Watson J, Burrows T. Measuring dietary intake in children and adolescents in the context of overweight and obesity. *Int J Obes*. 2010;34(7):1103-1115. doi:10.1038/ijo.2009.241.

109. Brogden N, Almiron-Roig E. Food liking, familiarity and expected satiation selectively influence portion size estimation of snacks and caloric beverages in men. *Appetite*. 2010;55(3):551-555. doi:10.1016/j.appet.2010.09.003.

110. Brogden N, Almiron-Roig E. Estimated portion sizes of snacks and beverages differ from reference amounts and are affected by appetite status in non-obese men. *Public Health Nutr*. 2011;14(10):1743-1751. doi:10.1017/S1368980011000528.

111. Beasley LJ, Hackett AF, Maxwell SM, Stevenson L. The effect of a dietary preload on estimation of usual food portion size by photograph in female volunteers. *J Hum Nutr Diet*. 2004;17(3):219-225. doi:10.1111/j.1365-277X.2004.00515.x.

112. Robinson E, Oldham M, Cuckson I, Brunstrom JM, Rogers PJ, Hardman CA. Visual exposure to large and small portion sizes and perceptions of portion size normality: Three experimental studies. *Appetite*. 2016;98:28-34. doi:10.1016/j.appet.2015.12.010.

113. Hernández T, Wilder L, Kuehn D, et al. Portion size estimation and expectation of accuracy. *J Food Compos Anal*. 2006;19:S14-S21. doi:10.1016/j.jfca.2006.02.010.

114. Japur CC, Diez-Garcia RW. Food energy content influences food portion size estimation by nutrition students. *J Hum Nutr Diet*. 2010;23(3):272-276. doi:10.1111/j.1365-277X.2010.01042.x.

CHAPTER 3. COMPARISON OF FOUR DIFFERENT PHOTO-BASED FOOD VISUAL ESTIMATION SYSTEMS BASED ON INFLUENCING FACTORS

Modified from a paper to be submitted to *Journal of Appetite*

Yuanying Lou,[1] Huaiqing Wu,[2] and Lorraine Lanningham-Foster[1*]

[1]Department of Food Science and Human Nutrition, Iowa State University, Ames, IA

[2]Department of Statistics, Iowa State University, Ames, IA

[*]*Lorraine Lanningham-Foster will be the corresponding author (lmlf@iastate.edu)*

Abstract

Background: Valid methods for quantifying food intake are essential to our understanding of people's dietary intake and weight regulation. Various visual estimation systems have been used in previous research to estimate food waste or consumption. **Objective:** This study aimed to compare four visual estimation systems and identified the influence of personal and food-related factors on different systems. **Methods:** A photo-based food visual estimation online survey was developed and sent to the entire community of a large mid-west university. Survey participants were asked to estimate food waste using four visual estimation systems: Third/Quarter/Eighth/Continuous. Personal information was also collected. **Outcome measures**: Root Mean Square Error (RMSE) was calculated for each participant performing each visual estimation system. Mixed models were developed to explore the influence of various factors on visual estimations, and pairwise comparisons of least square means of RMSE were conducted to compare the accuracies among the four visual estimation systems in the overall survey population or various sub-populations. **Results**: There was no significant difference in RMSEs between Quarter and Eighth systems (RMSE = 0.187±0.0077 and 0.192±0.0077, respectively, $p = 0.96$), however, they were both significantly lower than the other two systems ($p < 0.05$ in all related pairwise comparisons). Although gender did not have a significant influence on the overall RMSE across the four systems ($p = 0.12$), the influence of gender in different systems was significantly different ($p = 0.007$). There was a quadratic relationship between age and RMSE (p value = 0.003 and 0.005 for age and age square, respectively). The only significant difference among different major/job background groups was observed between Food/Nutrition- related majors and Other Majors ($p = 0.01$). The RMSE of liquid food was significantly lower than the solid food with certain shape or defined units ($p < 0.001$), which was significantly lower than the amorphous food ($p < 0.001$). There was a significant quadratic relationship observed between the overall RMSE and the waste percentage ($p = 0.56$ for waste percentage and <0.001 for waste percentage square, respectively). Eighth system was shown to be the only system that would not be influenced by any of the examined factors. The majority of the survey population (n= 59%) preferred to use the Quarter system. **Conclusion**: Quarter and Eighth systems were better choices than Third and Continuous systems, considering the accuracy, preference, and stability.

Key words: visual estimation; photo-based; rating scale; accuracy and reliability;

Introduction

Valid dietary assessment methods play a vital role in providing insights into people's dietary intake and nutritional status.[1] In some intervention studies, dietary data could be used to measure the impacts of interventions on influencing behavioral changes.[2–4]

Self-reported dietary assessment methods including 24-hour dietary recall, dietary records, food frequency questionnaire (FFQ), and diet history are the most commonly used methods for dietary intake analysis in adults.[5] The quality of self-reported dietary data relies on a person's willingness to report, their ability to remember all eaten food in details, and their ability to estimate portion size accurately.[5] Self-reported dietary intake reports have been criticized for their validity and reliability.[6] Recovery biomarkers, such as doubly labelled water (DLW), as the reference measurement for total energy expenditure, can help identify the level of accuracy of self-reported dietary data. Depending on the assessment methods and the responding population, energy intake is underreported by 4-37%. [7,8] Therefore, researchers were motivated to apply alternative dietary assessment methods to improve the accuracy of dietary intake analysis.

Manually weighing food waste, i.e. weighing method, was developed and widely used in research, especially in plate waste studies conducted in school programs.[9] It provides accurate and detailed information for individual food waste and consumption, and usually serves as a baseline gold standard.[9,10] However, disadvantages, including that it is time-consuming, costly, interruptive, and requires a large space for holding trays and weighing wastes, make this method not very practical for being applied in large-scale studies.[6,9]

Visual estimation methods have attracted much attention recently due to their unobtrusiveness, easy implementation, higher flexibility, and cost effectiveness.[6,10] The visual estimations could be done either onsite through direct observation, or remotely using photos taken before and after eating.[9–13] In direct onsite observation method, trained observers estimate food waste by observing food trays before and after eating.[10] This method has been widely applied in nutrient intake analysis and eating behaviors studies in school cafeteria and other public eating settings.[14–16] However, the onsite estimations still put some burden on observers due to the time pressure. In addition, observers need to memorize the initial portion size for each food item when estimating the waste percentage after eating, which is in particular difficult for the food items without standard initial portion sizes. For example, fruits and fresh vegetables are routinely obtained from school salad bar by students themselves which makes initial portion size quite variable.

The rapid development and widespread use of digital cameras and wireless communication devices (such as smartphones) has led to improvements in dietary assessment. Instead of having observers estimate food waste and consumption in the eating environment, photos can be taken before and after eating using digital cameras to record food selection and waste. After the photo collections, trained researchers can conduct estimations without time pressure by comparing the before- and after-photos shown on the computer screen.[6,11,12,17,18] Compared with the onsite visual estimation method, the photo-based visual estimation provides several additional advantages, such as more convenient applications in school or other public settings, less burden on researchers without requiring estimating in a limited time period, more flexibility, and rapid acquisition of data.[6]

Various rating scales have also been used in visual estimations, such as the five-point scale (estimating waste in the scale of all, ¾, ½, ¼ or less wasted), four-point scale (estimate waste in the scale of all, 2/3, 1/3, and none wasted), 10% scale (estimate waste in the unit of 10%), and 1% scale (estimations represented in the nearest percentile). [9,10,19–22] However, there have been a few studies comparing the accuracies of different rating scales. Many studies have reported the validity of the visual estimation by comparing to the DLW method or weighing method.[10,13,19,23–26]. However, there were no validation studies related to different rating scales by comparing them to one golden standard. Therefore, the primary objective of this study was to compare the accuracies of four different rating scales through comparisons between the estimation values and the true weights of individual food items. In previous research, the names of different rating scales were confusing and prone to misunderstandings. For example, two research articles mentioned using four-point scales in their visual estimations, but the interpretations of rating scale numbers were different in the two articles.[9,27] In one article, the interpretation of the four-point scale was: 0-nothing eaten; 1-one bite eaten; 2-more than one bite but not whole portion eaten; 3-whole portion eaten.[27] However, in another article, the interpretation was: 0-none wasted, 1-1/3 wasted, 2-2/3 wasted, 3-all wasted.[9] In order to reduce the confusion and interpret in a uniform way, in this study, the term ‘system’ represents the rating scale, and all systems describe the eating status from the perspective of food waste, not food consumption. Third system (describe food waste using how many third(s)), Quarter system (describe food waste using how many quarter(s)), Eighth system (describe food waste using how many eighth(s)), and Continuous system (describe food waste using how many percentage(s)) are the four systems explored in this study for their accuracies.

In addition to the use of different rating scales possibly influencing the accuracy of visual estimation, some personal factors or food-related factors might also influence the estimation accuracy. Gender, age, BMI, and major or job background have been reported in previous research as factors that would impact the accuracy of visual estimation.[28–31] The influence of the same factor was reported to be different, some were even contradictive, in different research studies due to the different study populations or different study designs. For example, Timon and colleague (2017) found that older adults age 65 years or older had the similar ability of performing visual estimations as younger adults aged 18 to 40 years.[30] However, Nelson et al. (1996) found that older adults tended to overestimate the portions size compared with younger adults.[29] Food type and portion size were also found to influence the accuracy of visual estimations. The visual estimations for solid food with either certain shape (e.g. hamburger) or defined units (e.g. fish sticks) were found to be more accurate than amorphous food (e.g. spaghetti or mashed potatoes).[32,33] Food with small portion size tended to be overestimated, but food with large portion size tended to be underestimated.[29,34] However, there were few studies investigating the influence of various factors on the different visual estimation rating scales. Hence, the second objective of this study was to explore the influence of some personal factors including gender, age, BMI, and major/job background, and some food-related factors including food types, initial portion size, and wasted percentages, on the accuracies of four visual estimation systems.

Methods

Developing a Photo-Based Survey for Food Waste Visual Estimation

The survey was designed as an online survey and developed using Qualtrics survey software (Qualtrics Software Company, Provo, Utah), with the aim to compare the accuracies of the four visual estimation systems: Third system, Quarter system, Eighth system, and Continuous system.

Survey structure and content

The complete survey appears in Appendix B. For each visual estimation system, eight pairs of photos were included, and each pair contained a before- and after-consumption photo. The first pair of photos in each visual estimation system was used as an example to instruct participants how to use that particular estimation system. The remaining seven pairs of photos in each system were the survey questions, which asked participants to estimate how much was wasted for each food item by comparing the before- with the after-consumption photo. In each plate (counted as one meal), one main dish and one or two side dishes were included. The estimations of the food items in one plate was set as one question, and the individual food item estimations were the sub-questions under that plate. To make the estimations in one visual estimation system comparable to other systems and reduce the influence from the confounding factors as much as possible, the order and content of plates with certain dishes were similar among the four systems.

The order of the four systems was randomized for each survey participant.

Four visual estimation systems used in the survey

Before asking the participants to estimate food waste using a particular system, instructions were provided to teach them how to use that estimation system by showing an example picture.

<u>Third system</u>: Describe food waste using how many third(s) were left.

<u>Quarter system</u>: Describe food waste using how many quarter(s) were left.

<u>Eighth system</u>: Describe food waste using how many eight(s) were left.

<u>Continuous system</u>: Describe food waste using how many percentage(s) were left.

In the Third, Quarter, and Eighth systems, participants could select the number to indicate how much food was wasted based on their estimations. In the Continuous system, a sliding bar with the range from 0 to 100 was provided and participants were instructed to drag the sliding bar to indicate the exact percentage of food waste.

Personal information collection

After estimating food waste using four visual estimation systems, participants were also asked to provide information about their gender (Male/Female/Other), age (years), height (cm/inch) and weight (kg/lb.), and major/job area. No names or identifying factors were collected, and none of the information collected was matched to participants.

At the end of survey, participants were asked to submit an email address if they wanted to be entered into a drawing. Three participants were selected through the drawing to receive a $25 gift card per person. Email addresses were collected using a separate survey without linking to other parts of the data.

Recruitment of Survey Participants

The study was reviewed by Iowa State University *Institutional Review Board* (IRB) and was deemed as "exempt". Written informed consents from survey participants were waived in this study (IRB#17-078, Appendix C.).

The link of the online survey was sent through mass email to the entire community of a large mid-west university including all students, faculties, and staff. The online survey was opened on March 29, 2017 and closed on April 7, 2017. During this period, participants could answer the survey any time. The total amount of time for completing the survey was estimated to be 10-15 minutes, but there was no time-limit for finishing the survey. Participation was completely voluntary, and participants could stop the survey at any time without penalty or negative consequences. The participants were instructed at the very beginning that they should be 18 years and older to participate.

Data Processing and Analyzing

Establishing the datasets for data analysis

A total of 1,497 survey responses were received from the participants. To guarantee the quality of the data, only the responses which met certain criteria were selected to establish the datasets used for analysis. Two datasets were established to separately explore the influence of personal factors and food-related factors. Selection criteria for the two datasets were set by the research team. For Dataset 1 that was to detect the influence of personal factors, only responses with complete personal information including gender, age, height and weight, and major/job area background were selected. This resulted in 862 surveys for Dataset 1. For the Dataset 2 that used to detect the influence of food-related factors, only responses with 100% complete food estimations were selected, and the personal information may have been incomplete. This resulted in 419 surveys for Dataset 2.

Calculating BMI

In the survey, participants were asked to report their height (either in centimeters or inches) and weight (either in kilograms or pounds). If they reported their height in inches or weight in pounds, inches were converted to centimeters and pounds were converted to kilograms. Then Body Mass Index (BMI) was calculated following the formula:

$BMI = weight\ (kg) / [height\ (m)]^2$

According to CDC standards, BMI was divided into four weight status categories to further explore their influence on food visual estimations: underweight (BMI <18.5 kg/m^2), normal weight (BMI within the range of 18.5-24.9 kg/m^2), overweight (BMI within the range of 25-29.9 kg/m^2), and obesity (BMI ≥ 30 kg/m^2).[35]

Major category

We wanted to explore the potential impact that major/job focus might have on food visual estimations. Previous research has provided evidence to suggest the nutrition or food-related knowledge and background may have a positive influence on food visual estimations.[30] Therefore, the first major category was Food/Nutrition-related including food science, nutritional science, dietetics, diet and exercise, kinesiology, and hospitality. Because visual estimations involve people's capacity of visual identification and processing, some majors that include related systematic training may help improve the visual sensitivity and positively influence visual estimations, such as Design-related majors and Engineering-related majors. Food visual estimations also deal with the volume/portion change, so people with training or experience related to using volume (e.g. acquiring experience from doing biological or chemistry experiments) may have greater potential to estimate volume more accurately. Natural science-related majors such as biology, chemistry, agriculture, and animal science were selected. All other majors not belonging to any of the four main major categories mentioned above, were included in the last category- Other majors.

Majors included in each main major category are summarized in Appendix D. Our research team used the major/program descriptions from the university website as the reference to help them select and classify majors into each category.

Food category, initial portion size and waste percentage

Thirteen foods were used in the survey, and categorized into three types:

Type 1- food with certain shape or defined units. In this type, food either had a certain shape such as beefsteak, or contained multiple pieces which could be easily counted, such as fish sticks.

Type 2-Amorphous food or food uncountable. In this type, food either is amorphous, such as mash potatoes, or could not be counted easily, such as green peas.

Type 3-Liquid. Only one food item contained in this type that is fruit cup.

Specific foods categorized into each type were summarized in Appendix E. Each food item had a unique initial portion size (represented in grams). A total of 88 initial portion sizes were included in this survey. Wasted percentage was calculated for each food item following the equation: *Wasted percentage = food waste (gram) / initial portion size (gram)*

Calculating Root Mean Square Error (RMSE)

RMSE quantifies the estimation error on average. It was calculated following the equation:

True values are Y_i *(i=1, 2, …, n), and the estimations are* $Y^{\wedge}$*. Estimation errors od* $e_i = Y_i - Y^{\wedge}$

$$RMSE=\sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}$$

RMSE could be calculated averaging over an individual, or a specific visual estimation system, or a specific food type, or an examined personal factor category.

Statistical Models

The statistical analysis was performed via Statistical Analysis Software 9.4 (SAS Institute, Cary, NC). The level of statistical significance was set as 0.05. Mixed models were established to analyze the influence of various visual estimation systems, personal factors, and food-related factors on the accuracy of visual estimations.

In Dataset 1, a mixed model was established to analyze the influence of visual estimation systems and examined personal factors. The RMSE for each individual using a specific visual estimation system was the response outcome. Visual estimation systems (Third/Quarter/ Eighth/Continuous system), gender, age, BMI, major/job categories, and the interactions between visual estimation systems and each of the personal factors were treated as fixed effects. The differences among individuals were treated as random effects.

Four similar mixed models were established in each visual estimation system separately to explore the influence of personal factors. The RMSE for each individual using that specific visual estimation system was the response outcome. Gender, age, BMI, and major/job categories were utilized as fixed effects. The differences among individuals were utilized as random effects.

In Dataset 2, the RMSE for each individual using a specific visual estimation system estimating a certain food type was the response outcome. Visual estimation systems, food types, and the interactions between visual estimation systems and food types were treated as fixed effects. The difference among individuals were random effects. Linear regression model and quadratic polynomial model was established between RMSE for each food item averaging over the entire survey responses in Dataset 2 and either initial portion size or wasted percentage.

Results

Descriptive Characteristics of Study Participants

Survey responses were received from a total of 1,479 participants. Only responses which met certain criteria were selected to establish two databases, and they were called 'survey population' hereafter in this paper. In Dataset 1, a total of 862 responses with complete personal information were selected to be used in the data analysis for detecting the influence of various personal factors on the accuracy of visual estimations. There were 419 responses with 100% complete food visual estimations selected to establish Dataset 2 to explore the influence of food-related factors on visual estimations. The basic demographic characteristics of the two survey populations are summarized in Table 3.1. Respondents were mostly female, young adults, and normal weight. Their BMI distributions appears in Figure 3.1. Greater than 50% of the survey population fell into the BMI normal category, which was higher than the percentage of people with normal weight status in the general U.S population (33%). Contrarily, the percentages of people with overweight or obesity in two survey populations were both lower than those in the general U.S population.

Comparing RMSEs of Four Visual Estimation Systems across the Entire Survey Population in Dataset 1

Results of comparing the RMSEs among the Third, Quarter, Eighth, and Continuous systems across the entire survey population in Dataset 1 are shown in Figure 3.2. There was no significant difference between the Quarter and Eighth systems (RMSE = 0.187±0.0077 and 0.192±0.0077, respectively, mean ± SEM, $p = 0.96$). However, they were both significantly lower than the other two systems ($p < 0.05$ in all related pairwise comparisons). Continuous system was slightly lower than Third system (RMSE = 0.2291 ±0.0077 and 0.2309 ±0.0077, respectively, shown as mean ± SEM), but the difference between the two was not significant ($p=0.86$).

The Influence of Various Personal Factors on RMSEs of Four Visual Estimation Systems

Among the personal factors examined in this study (including gender, age, BMI and major/job background), age and major/job background had a significant influence on the overall RMSE (meaning the RMSE across the four visual estimation systems, $p=0.003$ for both). Although gender might not influence the overall RMSE significantly ($p = 0.12$), the influence of gender on the accuracy of visual estimations using different estimation systems was significantly different ($p = 0.007$). The following parts will present the influence of each factor in detail, and compare the RMSEs of the four estimation systems in different sub-populations categorized by specific personal factors.

The influence of gender on RMSE

The overall RMSEs were calculated in males and females, and the comparison is shown in Figure 3.3. The overall RMSE in females was slightly lower than that in males (RMSE = 0.207 ±0.0024 and 0.211 ±0.0024, respectively, shown as mean ± SEM), however, the difference was not significant ($p = 0.2$).

Comparing RMSEs of the four visual estimation systems in males and females separately

Although the RMSE of each system was different in males and females, comparison among the four systems in the male or female population followed the same pattern as observed in the entire survey population without considering gender (Table 3.2). RMSEs of the Quarter and Eighth systems were significantly lower than the Third and Continuous system ($p< 0.05$ in all related pairwise comparisons).

The influence of age on RMSE

Age significantly influenced the overall RMSE. Figure 3.4 A reveals a quadratic relationship between age and the overall RMSE ($p = 0.003$ and 0.005 for age and age square, respectively).This quadratic relationship was more obvious in the Quarter system (Figure 3.4 B). By fitting the quadratic polynomial relationship, age was divided into four different groups to further study their influence on the overall RMSE. Group 1: 18-30 years. Group 2: 31-40 years. Group 3: 41-50 years. Group 4: above 50 years.

The influence of various age groups on RMSE

The overall RMSE in Group 3 (41-50 years) was the lowest among the four groups, followed by Group 4, Group 1, and then Group 2 (RMSE = 0.202 ± 0.0049, 0.206 ± 0.0045, 0.209 ± 0.0039, 0.210 ± 0.0046, respectively, shown as mean ± SEM). However, the difference of RMSEs between any two age groups was not statistically significant (Figure 3.5).

Comparing RMSEs of the four visual estimation systems in various age groups

In Groups 1 and 3, the patterns of the comparison of RMSEs among the four systems were the same as observed in the entire survey population. However, the patterns changed in Group 2 and 4 (Table 3.3). In Group 2, the order of RMSEs of the four systems from the smallest to the largest was: Quarter system, Eighth system, Third system, and Continuous system. Among all pair-wised comparisons, the only significant difference was observed between Quarter and Continuous systems (p= 0.03). However, in Group 4, the order of RMSEs of the four systems in from the smallest to the largest was: Eighth system, Quarter system, Continuous system, and Third system. The only significant difference was between Eighth and Third systems (p = 0.02).

The influence of BMI on RMSE

Figure 3.6 shows the relationship between BMI and the overall RMSE. Unlike age, the relationship between BMI and the overall RMSE did not fit the quadratic polynomial model (p = 0.45 and 0.19 for BMI and BMI square, respectively). Based on the CDC, standard weight status categories are used to interpret BMI in adults.[35] Therefore, the survey population in Dataset 1 was divided into four categories to further explore the influence of weight status on RMSE: underweight, normal weight, overweight and obesity. RMSEs of the four visual estimation systems were compared in the four BMI categories.

The influence of the four BMI categories on RMSE

The overall RMSE in the overweight category was the lowest among the four categories (0.204 ± 0.0041), the categories of obesity and normal weight followed (0.205 ± 0.0041 and 0.206 ± 0.0039, respectively, shown as mean ± SEM), and the underweight category was at the last with the largest RMSE (0.210 ± 0.0067, shown as mean ± SEM). However, the difference of RMSEs between any two BMI categories was not statistically significant (Figure 3.7).

Comparing RMSEs of the four visual estimation systems in the four BMI categories

Table 3.4 summarizes the results of separately comparing RMSEs of the four visual estimation systems in each BMI category. In the category of normal weight, the comparison of RMSEs was the same as observed in the entire survey population. While in the category of obesity, there was no significant difference between any two systems, meaning the accuracies of the four visual estimation systems were similar. In the underweight category, the order of RMSEs from the smallest to the largest was: Eighth system, Quarter system, Third system, and Continuous system. Among all pair-wised comparisons, the only significant difference was between the Eighth and Continuous systems ($p= 0.03$). In overweight category, RMSEs of the Quarter and Eighth systems were both significantly lower than the Third system ($p = 0.001$ and 0.03, respectively). In addition, RMSE of the Quarter system was significantly lower than the Continuous system ($p = 0.004$). RMSE of the Eighth system was in between the Quarter and Continuous system, but the difference between Eighth and Quarter systems, or between Eighth and Continuous systems, was not significant ($p =1$ and 0.08, respectively).

The influence of major/job area on RMSE

Major/job background was divided into five groups: Food/Nutrition-related, Design-related, Engineering-related, Natural Science- related, and Other Majors (details of classification were described in Methods and Appendix D). The order of the overall RMSEs from smallest to largest in the five major/job area was: Food/Nutrition-related, Engineering-related, Natural Science-related, Other majors**,** and Design-related (RMSE = 0.200 ± 0.0048, 0.203 ± 0.0045, 0.206 ± 0.0042, 0.210 ± 0.0040, 0.211 ± 0.0057, respectively, shown as mean ± SEM, Figure 3.8). The only significant difference was observed between the groups of Food/Nutrition-related and Other Majors ($p= 0.01$).

Comparing RMSEs of the four visual estimation systems in various major/job groups

The comparison of RMSEs of the four visual estimation systems in each major/job area is shown in Table 3.5. In the group of Other Majors, the pattern of comparison was the same as in the entire survey population. Nevertheless, in the group of Design-related majors, there was no significant difference between any two systems, which indicated that the accuracies of the four systems were similar. In the group of Food/Nutrition -related majors, the RMSE of the Quarter and Eighth systems were significantly lower than the Third system (p = 0.01 and 0.02, respectively). Both of Quarter and Eighth systems were lower than the Continuous system as well, however, such difference was not statistically significant (p = 0.15 and 0.23, respectively). In the group of Engineering-related majors, the Quarter system was with the smallest RMSE (0.176 ± 0.0086, shown as mean ± SEM), and was significantly lower than the Third or Continuous system (p = 0.03 and 0.04, respectively). The RMSE of the Quarter system was slightly lower than the Eighth system, but the difference was not significant (p= 0.56). In the group of Natural Science-related majors, the order of RMSEs of the four systems from the smallest to the largest was: Quarter system, Eighth system, Third system, and Continuous system. Among all pair-wised comparisons, the significant difference was observed between the Quarter and Continuous systems (p= 0.001), and between the Eighth and Continuous systems (p = 0.004).

The Influence of Various Personal Factors on RMSE in Each Visual Estimation System

Separately exploring the influence of various personal factors on RMSE in each visual estimation system, we found the Eighth system was the only one that was not be affected by any of the examined personal factors. In the Quarter and Third system, gender was the factor that had a significant influence on RMSE (Figure 3.9). The RMSE in females was significantly lower than the males in both systems. Major/job background had a significant influence on RMSE in the Quarter and Continuous systems (p= 0.05 and 0.02, respectively).

The Influence of Food Factors on RMSEs of the Four Visual Estimation Systems

For each participant, RMSE using a specific visual estimation system was calculated in each food type separately.

The influence of food types on RMSE

Food types exerted a significant influence on the overall RMSE ($p<0.001$). Figure 3.10 shows Type 3 (liquid food) has the lowest RMSE (0.105 ± 0.0037, shown as mean ± SEM), which was significantly lower than Type 1(food with certain shape or countable pieces) and Type 2 (amorphous food or food uncountable, $p <0.001$ for both comparisons). The difference between the RMSEs of Type 1 and 2 was also statistically significant (0.158 ± 0.0037 and 0.230 ± 0.0037, respectively, shown as mean ± SEM, $p<0.001$).

Comparing RMSEs of the four visual estimation systems in different food types

Table 3.6 summarizes the results of comparing RMSEs among the four systems in each food type. In Type 1, the lowest RMSE was observed in the Eighth system (0.099 ± 0.0052, shown as mean ± SEM), which was significantly lower the other three systems ($p <0.001$ for all). Following the Eighth system was the Quarter system (0.145 ± 0.0052, shown as mean ± SEM), whose RMSE was significantly lower than that of the Continuous and Third systems ($p <0.001$ for both). However, in Type 2, the Quarter system had the lowest RMSE (0.205 ± 0.0052), which was only slightly lower than the Eighth system ($p = 0.07$) but significantly lower than the Third and Continuous system ($p <0.001$ for both). Comparison of RMSEs in Type 3 was similar as in Type 1. However, in Type 3, there is no significant different between the Quarter and Third systems ($p = 1$).

The influence of food initial weights and wasted percentages on RMSE

Each food item included in this survey had a unique initial weight and waste percentage. There were 88 total initial weights and waste percentages analyzed. RMSE was calculated for each initial weight /waste percentage using a specific visual estimation system across the entire survey population in Dataset 2. There was no significant linear or quadratic relationship between the initial weight and the overall RMSE or the RMSE of each system. However, there was a significant quadratic relationship between the waste percentage and the overall RMSE (Figure 3.11 A, $p = 0.56$ for waste percentage and $p < 0.001$ for waste percentage square). The quadratic relationship was not observed in the Third or Continuous system, but was in the Quarter and Eighth systems (Figure 3.11 B and C).

The Preference on Using the Four Visual Estimation Systems

In the survey, there was a question asking the participant to select one method (only one) that they liked the most and preferred to use in the future. Results showed 59% of the survey population in Dataset 1 select the Quarter system, followed by the Continuous system (28%). Only 10% of the survey population selected the Eighth system and 3% selected the Third system (Figure 3.12).

Discussion

Adopting valid dietary assessment methods in research and dietetic practice plays a very important role in understanding people's dietary intake to assess nutrient intake as well as body weight regulation (caloric intake). Compared to the self-reported dietary records and the weighing method, photo-based visual estimation methods have drawn much more attention in recent years due to its cost-effectiveness, labor-saving, and high-flexibility.[6,17,21,24,25,36,37] In previous literature, different visual estimation rating scales have been used, such as the six-point scale,[9,37–41] the five-point scale (called the Quarter system in this study), [9,10,19,42–45] and the 10%-increment scale,[20,21,46,47] Many studies were designed to explore the validity of the visual estimation methods by comparing to other "gold standards" such as the weighing method or the DLW method.[6,9,10,17,25,40,41,48] However, few studies compared the accuracies of the various rating scales. Therefore, by developing a photo-based food visual estimation survey, this study aimed to compare the accuracies of four visual estimation systems (Third/Quarter/ Eighth/Continuous system) across an entire survey population or in various sub-populations.

To compare the accuracies of two dietary assessment methods, the Pearson correlation and Bland -Altman plot analysis were commonly used in literature.[6,11,12,17,25] However, such statistics can only provide information about the correlations between the two methods, rather than their agreement. In other words, a high correlation does not necessarily guarantee a high agreement. To better indicate the agreement, Kappa or weighed Kappa statistic might be considered.[19,49] Although weighed Kappa assigns less weight to agreement as categories become further apart,[50] this statistic is still more acceptable used in categorical data analysis. Therefore, in our study, RMSE, which measures the average estimation errors compared to the true values, was selected as the indicator for the accuracy.

Results showed the RMSEs of the Quarter and Eighth systems were significantly lower than the Continuous and Third system across the entire survey population in Dataset 1 (Figure 3.1). There was no significant difference either between the Quarter and Eighth systems, or between the Continuous and Third systems. Considering some personal factors may provide a influence on the visual estimations, the survey population was divided into various sub-populations by different factors. In this study, gender, age, BMI, and major/ job area were examined, and the entire survey population was divided into 15 sub-populations.

Comparing RMSEs of the four visual estimation systems in each sub-population, the patterns observed in the sub-populations were similar as observed in the entire survey population. The same pattern was found in six sub-populations: Female, male, participants with the age of 18-30 years, participants with the age of 41-50 years, participants with normal BMI, and participants with Other Majors. In these six sub-populations, the RMSEs of the Quarter and

Eighth systems were significantly lower than the Continuous and Third systems. Only in two sub-populations, there was no significant difference between any two of the four systems: participants with obese and participants with the Design-related majors/jobs. In other words, the accuracies of the four systems in these two sub-populations had no significant difference. In the other seven sub-populations, similar patterns as in the entire survey population were observed. By ranking RMSEs of the four systems from the lowest to highest in these seven sub-populations, the Quarter and Eighth systems kept the top two positions. Considering the overall analysis, the Quarter and Eighth systems might be better choices than the Third and Continuous systems for use as rating scales in visual estimations.

However, choosing a proper visual estimation rating scale for a particular study should be more than simply considering the accuracy. The stability (in this paper, meaning the resistance to the influence exerted by other factors) and people's preference are both important aspects that should be considered as well. A mixed model was established in each visual estimation system to explore the influence of various personal factors on RMSE. Results indicated the Eighth system was more robust without influencing by the examined personal factors. However, the Quarter system was selected over the other three in terms of people's preference.

The significant influence on the accuracy of visual estimations may be not only from the rating scales selected, but also from various personal or food-related factors. Gender, age, BMI, participants' occupation/ background, food type, portion size, food or energy density, appetite status have shown to significantly influence the accuracy of visual estimations.[16,28–33,51,52] Therefore, the second objective of this study was to explore the influence of various factors including gender, age, BMI, major/job area, food type, initial weight, and food waste percentage.

Our results showed the overall RMSE was lower in females than males, consistent with the previous findings showing males tended to estimate with greater errors than female.[28,29]. Examining the gender influence in each visual estimation system separately, the RMSE in females was significantly lower than males using the Quarter and Third systems.

Timon and colleague (2017) observed that older adults (aged 65 years and older) and younger adults (aged between 18 and 40 years) had similar ability to perform visual estimations.[30] However, in another study led by Nelson et al.(1996), adults aged 65 years and older were found to overestimate the portion size more than younger adults.[29] In our study, age was examined as a continuous variable first to explore its influence. A significant quadratic relationship was found between age and the overall RMSE, especially in the Quarter system (Figure 3.4 A and B). To gain an in-depth understanding of the age influence, age was divided into four groups and the overall RMSE were compared among the groups. Group 3 (between 41 and 50 years) had the lowest RMSE. Group 2 (aged between 31 and 40 years) had the highest RMSE. Group 4 and 1 was in between. However, the difference between any two of the groups was not significant. The categorization of age (determining groups) might influence the comparisons. Using the estimates calculated to develop the quadratic model between age and RMSE, people with the age of 41 was estimated to have the lowest RMSE. However, in our group categories, age of 41 was at the lower end of Group 3 (aged from 41-50 years). This group categorization might counterbalance some differences, providing one possible explanation for this result that no significant difference was observed between any two age groups.

People with a BMI $\geq$ 30 kg/m^2 (obesity category) was shown in a previous study to be associated with an 8% underestimate of portion size.[31] However, in our study, people with a BMI within 25-29.9 kg/m^2 (overweight category) had the lowest RMSE, and people with a BMI <18.5

(underweight category) had the highest RMSE. People with a BMI within 18.5-24.9 kg/m^2 (normal weight category) and people with a BMI $\geq$ 30 kg/m^2 (obesity category) were in between. The difference between any two of the BMI categories was not significant in our study.

The research done by Timon et al. (2017) also found that the nutritionists participating in their study had less variability in estimating portion size compared to the people without nutrition professional background.[30] Our results was consistent with this finding, showing the participants with a Food/Nutrition-related background had the lowest RMSE compared to other major/job groups, although the difference was not always significant. This provides some supports for the necessity of designing a food visual estimation training: people's knowledge about food might help on improving the accuracy of portion size estimations.

Some studies have explored the influence of food types on visual estimation accuracy. Yuhas *et.al.* (1989) found in general solid food were estimated more accurately than liquid food, which were estimated more accurately than amorphous food.[33] However, in another article published by Hernandez and colleague (2006), the overall errors (mean ± standard error of mean (SEM)) for solid food, amorphous food, and liquid was shown to be 8.3% ± 2.3 %, -10% ± 2.7% , 19% ± 5%, respectively.[32] We also found a significant influence from food types on the accuracy of visual estimations; however, the influence from different types of food observed in our study was different from the previous two findings. Liquid food shown in our research had the lowest RMSE among the three types, which was significantly lower than solid food and amorphous food. RMSE of solid food was also significantly lower than amorphous food. One possible explanation is the number of food items presented in the three food types are not balanced. There were four food items in Type 1, and seven items in Type 2. However, only one food item (fruit cup) was presented in Type 3. The bias of analysis may be increased due to the unbalanced number of food items presented in each food type.

Hernandez *et al.* (2006) also reported food portion size was inversely correlated with the magnitude of estimation errors.[32] Comparably, Nelson and colleague (1996) found the large portion sizes tended to be underestimated but small portion sizes were overestimated.[29] We also observed a slight inverse relationship between the food initial weight and RMSE ($r = -0.0004$), however, it was not significant ($p = 0.17$). Additionally, the correlation between the wasted percentage and RMSE in the Quarter and Eighth system fits the quadratic polynomial model (Figure 3.11 B and C). This indicated that the estimation accuracy was higher when the weight of food changed little (none/little wasted) or changed lot (all/most wasted). Nevertheless, the estimation accuracy was lower when the wasted percentage was around 50%.

RMSE is an effective indicator to show the average estimation error against true values. It can be easily calculated in each person, or in each visual estimation system, or in each food type, or across the entire survey population, or across the four visual estimation systems. However, RMSE does not show the direction of the error, which is overestimation or underestimation. This might be a limitation for using RMSE as the indicator. Therefore, adding other statistics, such as the percent error, might provide additional information to help us compare the accuracies of the four visual estimation systems. Another limitation in this study is the low diversity for participants regarding their education and socio-economic background. Besides faculty, staff, and students in a university, participants from other communities or backgrounds could be involved to reduce biases and better generalize the conclusion.

Conclusions

Overall, among the four visual estimation systems examined in this study, the Quarter system is a good choice to be used in visual estimations due to its high accuracy and high preference from estimators. The Eighth system is stable and could be considered when the estimators are from a more diverse population. Gender, age, BMI, major/job area, food type, and food waste percentage might influence the accuracy of food visual estimations.

Acknowledgements

This work was supported in part by the United States Department of Agriculture National Institute of Food and Agriculture (NIFA) grant 2014-08390 “Dissemination of the evidence-based SWITCH program for childhood obesity prevention.” This work is solely the responsibility of the authors and does not necessarily represent the views of the USDA.

Authors’ Contributions

YL and LLF was responsible for the study design. YL developed the survey and processed the survey responses. YL and HW analyzed the data. YL drafted the first manuscript with the contributions from LLF. All authors reviewed and commented on subsequent drafts of the manuscript

Author Disclosure Statement

No competing financial interests exist.

References

1. Hock K, Tallman D, Kaur D, Mat Daud Z, Khosla P, Karupaiah T. Dietary assessment methods. *J Ren Nutr Metab*. 2018;3(1):8. doi:10.4103/2395-1540.232539.

2. Williamson DA, Champagne CM, Harsha DW, et al. Effect of an Environmental School-Based Obesity Prevention Program on Changes in Body Fat and Body Weight: A Randomized Trial. *Obesity*. 2012;20(8):1653-1661. doi:10.1038/oby.2012.60.

3. Williamson DA, Copeland AL, Anton SD, et al. Wise Mind Project: A School-based Environmental Approach for Preventing Weight Gain in Children*. *Obesity*. 2007;15(4):906-917. doi:10.1038/oby.2007.597.

4. Williamson DA, Champagne CM, Harsha D, et al. Louisiana (LA) Health: Design and methods for a childhood obesity prevention program in rural schools. *Contemp Clin Trials*. 2008;29(5):783-795. doi:10.1016/j.cct.2008.03.004.

5. Boushey CJ, Spoden M, Zhu FM, Delp EJ, Kerr DA. Conference on "New technology in nutrition research and practice" Symposium 1: New technologies in dietary assessment New mobile methods for dietary assessment: review of image-assisted and image-based dietary assessment methods. 2016. doi:10.1017/S0029665116002913.

6. Williamson DA, Allen HR, Martin PD, Alfonso AJ, Gerald B, Hunt A. Comparison of digital photography to weighed and visual estimation of portion sizes. *J Am Diet Assoc*. 2003;103(9):1139-1145. doi:10.1016/S0002-8223(03)00974-X.

7. Thompson FE, Subar AF. *Nutrition in the Prevention and Treatment of Disease*. 3rd ed. San Diego; 2013. doi:10.1016/B978-0-12-802928-2.00001-1.

8. Moshfegh AJ, Rhodes DG, Baer DJ, et al. The US Department of Agriculture Automated Multiple-Pass Method reduces bias in the collection of energy intakes. *Am J Clin Nutr*. 2008;88(2):324-332. doi:10.1093/ajcn/88.2.324.

9. Comstock EM, St Pierre RG, Mackiernan YD. Measuring individual plate waste in school lunches. Visual estimation and children's ratings vs. actual weighing of plate waste. *J Am Diet Assoc*. 1981;79(3):290-296. http://www.ncbi.nlm.nih.gov/pubmed/7264115. Accessed January 15, 2018.

10. Hanks AS, Wansink B, Just DR. Reliability and accuracy of real-time visualization techniques for measuring school cafeteria tray waste: validating the quarter-waste method. *J Acad Nutr Diet*. 2014;114(3):470-474. doi:10.1016/j.jand.2013.08.013.

11. Martin CK, Newton RL, Anton SD, et al. Measurement of children's food intake with digital photography and the effects of second servings upon food intake. *Eat Behav*. 2007;8(2):148-156. doi:10.1016/j.eatbeh.2006.03.003.

12. Martin CK, Han H, Coulon SM, Allen HR, Champagne CM, Anton SD. A novel method to remotely measure food intake of free-living individuals in real time: the remote food photography method. *Br J Nutr*. 2009;101(3):446. doi:10.1017/S0007114508027438.

13. Martin CK, Correa JB, Han H, et al. Validity of the Remote Food Photography Method (RFPM) for Estimating Energy and Nutrient Intake in Near Real-Time. *Obesity*. 2012;20(4):891-899. doi:10.1038/oby.2011.344.

14. Perry CL, Bishop DB, Taylor GL, et al. A Randomized School Trial of Environmental Strategies to Encourage Fruit and Vegetable Consumption among Children. *Heal Educ Behav*. 2004;31(1):65-76. doi:10.1177/1090198103255530.

15. Friedman B., Hurd-Crixell SL. Nutrient Intake of Children Eating School Breakfast. *J Am Diet Assoc*. 1999;99(2):219-221. doi:10.1016/S0002-8223(99)00052-8.

16. Gittelsohn J, Shankar A V., Pokhrel RP, West KP. Accuracy of estimating food intake by observation. *J Am Diet Assoc*. 1994;94(11):1273-1277. doi:10.1016/0002-8223(94)92459-7.

17. Williamson DA, Allen HR, Martin PD, Alfonso A, Gerald B, Hunt A. Digital photography: A new method for estimating food intake in cafeteria settings. *Eat Weight Disord - Stud Anorexia, Bulim Obes*. 2004;9(1):24-28. doi:10.1007/BF03325041.

18. Swanson M. Digital Photography as a Tool to Measure School Cafeteria Consumption. *J Sch Health*. 2008;78(8):432-437. doi:10.1111/j.1746-1561.2008.00326.x.

19. Getts KM, Quinn EL, Johnson DB, Otten JJ. Validity and Interrater Reliability of the Visual Quarter-Waste Method for Assessing Food Waste in Middle School and High School Cafeteria Settings. *J Acad Nutr Diet*. 2017;117(11):1816-1821. doi:10.1016/j.jand.2017.05.004.

20. Smith SL, Cunningham-Sabo L. Food choice, plate waste and nutrient intake of elementary- and middle-school students participating in the US National School Lunch Program. *Public Health Nutr*. 2014;17(6):1255-1263. doi:10.1017/S1368980013001894.

21. Taylor JC, Sutter C, Ontai LL, Nishina A, Zidenberg-Cherr S. Feasibility and reliability of digital imaging for estimating food selection and consumption from students' packed lunches. *Appetite*. 2018;120:196-204. doi:10.1016/j.appet.2017.08.037.

22. Hakim SM, Meissen G. Increasing Consumption of Fruits and Vegetables in the School Cafeteria: The Influence of Active Choice. *J Health Care Poor Underserved*. 2013;24(2A):145-157. doi:10.1353/hpu.2013.0109.

23. Nicklas T, Saab R, Islam NG, et al. Validity of the Remote Food Photography Method Against Doubly Labeled Water Among Minority Preschoolers. *Obesity*. 2017;25(9):1633-1638. doi:10.1002/oby.21931.

24. Stumbo PJ. New technology in dietary assessment: a review of digital methods in improving food record accuracy. 2018. doi:10.1017/S0029665112002911.

25. Martin CK, Nicklas T, Gunturk B, Correa JB, Allen HR, Champagne C. Measuring food intake with digital photography. *J Hum Nutr Diet*. 2014;27(s1):72-81. doi:10.1111/jhn.12014.

26. Olafsdottir AS, Hörnell A, Hedelin M, Waling M, Gunnarsdottir I, Olsson C. Development and Validation of a Photographic Method to Use for Dietary Assessment in School Settings. Portero-Otin M, ed. *PLoS One*. 2016;11(10):e0163970. doi:10.1371/journal.pone.0163970.

27. Acredolo LP, Pick HL. OF A SCHOOL LUNCH PROGRAM'. @ *Psychol Reports*. 1975;37:33-34. http://journals.sagepub.com/doi/pdf/10.2466/pr0.1975.37.1.331. Accessed July 8, 2018.

28. Almiron-Roig E, Solis-Trapala I, Dodd J, Jebb SA. Estimating food portions. Influence of unit number, meal type and energy density. *Appetite*. 2013;71:95-103. doi:10.1016/j.appet.2013.07.012.

29. Nelson M, Atkinson M, Darbyshire S. Food photography II: use of food photographs for estimating portion size and the nutrient content of meals. *Br J Nutr*. 1996;76(1):31. doi:10.1079/BJN19960007.

30. Timon CM, Cooper SE, Barker ME, et al. A comparison of food portion size estimation by older adults, young adults and nutritionists. *J Nutr Health Aging*. June 2017:1-7. doi:10.1007/s12603-017-0937-9.

31. Nelson M, Atkinson M, Darbyshire S. Food Photography I: the perception of food portion size from photographs. *Br J Nutr*. 1994;72(5):649. doi:10.1079/BJN19940069.

32. Hernández T, Wilder L, Kuehn D, et al. Portion size estimation and expectation of accuracy. *J Food Compos Anal*. 2006;19:S14-S21. doi:10.1016/j.jfca.2006.02.010.

33. Yuhas JA, Bolland JE, Bolland TW. The impact of training, food type, gender, and container size on the estimation of food portion sizes. *J Am Diet Assoc*. 1989;89(10):1473-1477.

34. Ovaskainen M-L, Paturi M, Reinivuo H, et al. Accuracy in the estimation of food servings against the portions in food photographs. *Eur J Clin Nutr*. 2008;62:674-681. doi:10.1038/sj.ejcn.1602758.

35. Bhaskaran K, Douglas I, Forbes H, dos-Santos-Silva I, Leon DA, Smeeth L. Body-mass index and risk of 22 specific cancers: a population-based cohort study of 5·24 million UK adults. *Lancet*. 2014;384(9945):755-765. doi:10.1016/S0140-6736(14)60892-8.

36. Hawkins K, Apolzan J, Myers C, Martin C. The Assessment of Food Intake with Digital Photography. In: *Advances in the Assessment of Dietary Intake*. Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742: CRC Press; 2017:85-111. doi:10.1201/9781315152288-6.

37. Taylor JC, Yon BA, Johnson RK. Reliability and Validity of Digital Imaging as a Measure of Schoolchildren's Fruit and Vegetable Consumption. *J Acad Nutr Diet*. 2014;114(9):1359-1366. doi:10.1016/j.jand.2014.02.029.

38. Connors PL, Rozell SB. Using a visual plate waste study to monitor menu performance. *J Am Diet Assoc*. 2004;104(1):94-96. doi:10.1016/j.jada.2003.10.012.

39. Parent M, Niezgoda H, Keller HH, Chambers LW, Daly S. Comparison of Visual Estimation Methods for Regular and Modified Textures: Real-Time vs Digital Imaging. *JAND*. 2012;112:1636-1641. doi:10.1016/j.jand.2012.06.367.

40. Liz Martins M, Cunha LM, Rodrigues SSP, Rocha A. Determination of plate waste in primary school lunches by weighing and visual estimation methods: A validation study. *Waste Manag*. 2014;34(8):1362-1368. doi:10.1016/J.WASMAN.2014.03.020.

41. Kirks BA, Wolff HK. A comparison of methods for plate waste determinations. *J Am Diet Assoc*. 1985;85(3):328-331. http://www.ncbi.nlm.nih.gov/pubmed/3973322. Accessed January 19, 2018.

42. Niaki SF, Moore CE, Chen T-A, Weber Cullen K. Younger Elementary School Students Waste More School Lunch Foods than Older Elementary School Students. *J Acad Nutr Diet*. 2017;117(1):95-101. doi:10.1016/J.JAND.2016.08.005.

43. Wansink B, Just DR, Hanks AS, Smith LE. Pre-Sliced Fruit in School Cafeterias. *Am J Prev Med*. 2013;44(5):477-480. doi:10.1016/j.amepre.2013.02.003.

44. Orlowski M, Lee M, Spears W, et al. Patterns in Vegetable Consumption: Implications for Tailored School Meal Interventions. *J Sch Health*. 2017;87(5):346-352. doi:10.1111/josh.12504.

45. Cullen KW, Chen T-A, Dave JM, Jensen H. Differential Improvements in Student Fruit and Vegetable Selection and Consumption in Response to the New National School Lunch Program Regulations: A Pilot Study. *J Acad Nutr Diet*. 2015;115:743-750. doi:10.1016/j.jand.2014.10.021.

46. Williamson DA, Han H, Johnson WD, Martin CK, Newton RL. Modification of the school cafeteria environment can impact childhood nutrition. Results from the Wise Mind and LA Health studies. *Appetite*. 2013;61:77-84. doi:10.1016/j.appet.2012.11.002.

47. Cunningham-Sabo L, Lohse B, Smith S, et al. Fuel for Fun: a cluster-randomized controlled study of cooking skills, eating behaviors, and physical activity of 4th graders and their families. *BMC Public Health*. 2016;16(1):444. doi:10.1186/s12889-016-3118-6.

48. Burrows TL, Martin RJ, Collins CE. A Systematic Review of the Validity of Dietary Assessment Methods in Children when Compared with the Method of Doubly Labeled Water. *J Am Diet Assoc*. 2010;110(10):1501-1510. doi:10.1016/J.JADA.2010.07.008.

49. Oza-Frank R, Hade EM, Conrey EJ. Inter-Rater Reliability of Ohio School-Based Overweight and Obesity Surveillance Data. *J Acad Nutr Diet*. 2012;112(9):1410-1414. doi:10.1016/j.jand.2012.06.006.

50. Landis JR, Koch GG. The Measurement of Observer Agreement for Categorical Data. *Source: Biometrics BIOMETRICS*. 1977;33(33):159-174. http://www.jstor.org/stable/2529310. Accessed June 19, 2018.

51. Brogden N, Almiron-Roig E. Estimated portion sizes of snacks and beverages differ from reference amounts and are affected by appetite status in non-obese men. *Public Health Nutr*. 2011;14(10):1743-1751. doi:10.1017/S1368980011000528.

52. Japur CC, Diez-Garcia RW. Food energy content influences food portion size estimation by nutrition students. *J Hum Nutr Diet*. 2010;23(3):272-276. doi:10.1111/j.1365-277X.2010.01042.x.

Tables and Figures

Table 3.1. Demographic descriptions of the survey population.

Demographic characteristics	Dataset 1	Dataset 2
Total participants number	862	419
Female percentage (%)	67	65
Age (years)	31(14) [1]	29 (13) [1]
BMI (kg/m^2)	26 (6) [1]	26 (6) [1]

Note: 1. The data were represented as Mean (standard error of mean (SEM)).

Table 3.2: Comparison of RMSEs among the four estimation systems in the males and females

	Third System [1,2]	Quarter System [1,2]	Eighth System [1,2]	Continuous System [1,2]
Male	0.2321 (0.00475) [b]	0.2023 (0.00475) [a]	0.1958 (0.00475) [a]	0.2290 (0.00475) [b]
Female	0.2220 (0.00356) [b]	0.1895 (0.00356) [a]	0.1954 (0.00356) [a]	0.2349 (0.00356) [b]

Note: 1. Each system represented as the least square mean of RMSE (SEM) in the cell.
2. Non-overlap letter showed significant difference level compared in that specific gender sub-population, $p<0.05$.

Table 3.3: Comparison of RMSEs among the four estimation systems in different age groups

	Third System [1,2]	**Quarter System** [1,2]	**Eighth System** [1,2]	**Continuous System** [1,2]
Group 1: 18-30 y.o.	0.2301 (0.00778) [b]	0.1856 (0.00778) [a]	0.1865 (0.00778) [a]	0.2318 (0.00778) [b]
Group 2: 31-40 y.o.	0.2229 (0.00916) [ab]	0.1865 (0.00916) [a]	0.1928 (0.00916) [ab]	0.2335 (0.00916) [b]
Group 3: 41-50 y.o.	0.2266 (0.00974) [b]	0.1729 (0.00974) [a]	0.1789 (0.00974) [a]	0.2283 (0.00974) [b]
Group 4: Above 50 y.o.	0.2296 (0.009) [b]	0.1875 (0.009) [ab]	0.1815 (0.009) [a]	0.2240 (0.009) [ab]

Note: 1. Each system represented as the least square mean of RMSE (SEM) in the cell.
2. Non-overlap letter showed significant difference level compared in that specific age group, $p<0.05$.

Table 3.4: Comparison of RMSEs among the four estimation systems in different BMI categories

	Third System [1,2]	**Quarter System** [1,2]	**Eighth System** [1,2]	**Continuous System** [1,2]
Underweight [3]	0.2309 (0.01349) [ab]	0.1872 (0.01349) [ab]	0.1763 (0.01349) [a]	0.2453 (0.01349) [b]
Normal [3]	0.2272 (0.00771) [b]	0.1807 (0.00771) [a]	0.1879 (0.00771) [a]	0.2264 (0.00771) [b]
Overweight [3]	0.2278 (0.00814) [c]	0.1771 (0.00814) [a]	0.1865 (0.00814) [ab]	0.2242 (0.00814) [bc]
Obesity [3]	0.2234 (0.00816) [a]	0.1876 (0.00816) [a]	0.1889 (0.00816) [a]	0.2216 (0.00816) [a]

Note: 1. Each system represented as the least square mean of RMSE (SEM) in the cell.
2. Non-overlap letter showed significant difference level compared in that specific BMI category, $p<0.05$.
3. Standard weight status categories are based on CDC (https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html).

Table 3.5: Comparison of RMSEs among the four estimation systems in different major groups

	Third System [1,2]	Quarter System [1,2]	Eighth System [1,2]	Continuous System[1,2]
Food/Nutrition[3]	0.2324 (0.00932) [b]	0.1784 (0.00932) [a]	0.1849 (0.00932) [a]	0.2180 (0.00932) [ab]
Design [3]	0.2324 (0.01127) [a]	0.2019 (0.01127) [a]	0.1922 (0.01127) [a]	0.2335 (0.01127) [a]
Engineering [3]	0.2274 (0.00863) [b]	0.1797 (0.00863) [a]	0.1975 (0.00863) [ab]	0.2227 (0.00863) [a]
Natural Science [3]	0.2292 (0.00812) [bc]	0.1852 (0.00812) [a]	0.1927 (0.00812) [ab]	0.2351 (0.00812) [c]
Other [3]	0.2331 (0.00777) [b]	0.1916 (0.00777) [a]	0.1949 (0.00777) [a]	0.2362 (0.00777) [b]

Note: 1. Each system represented as the least square mean of RMSE (SEM) in the cell.
2. Non-overlap letter showed significant difference level compared in that specific major group, $p<0.05$.
3. The details related to major categorization in Appendix D.

Table 3.6: Comparisons of RMSEs among four estimation systems in different food categories

	Third System [1,2]	Quarter System [1,2]	Eighth System [1,2]	Continuous System [1,2]
Type 1: Certain shape/countable[3]	0.1978 (0.00521) [c]	0.1446 (0.00521) [b]	0.0985 (0.00521) [a]	0.1918 (0.00521) [c]
Type 2: Amorphous/uncountable[3]	0.2412 (0.00521) [bc]	0.2048 (0.00521) [a]	0.2238 (0.00521)[ab]	0.2500 (0.00521) [c]
Type 3: Liquid[3]	0.1028 (0.00521) [b]	0.1029 (0.00521) [b]	0.0492 (0.00521) [a]	0.1592 (0.00521) [c]

Note: 1. Each system represented as the least square mean of RMSE (SEM) in the cell.
2. Non-overlap letter showed significant difference level compared in that specific food category, $p<0.05$.
3. The details related to food type categorization in Appendix E.

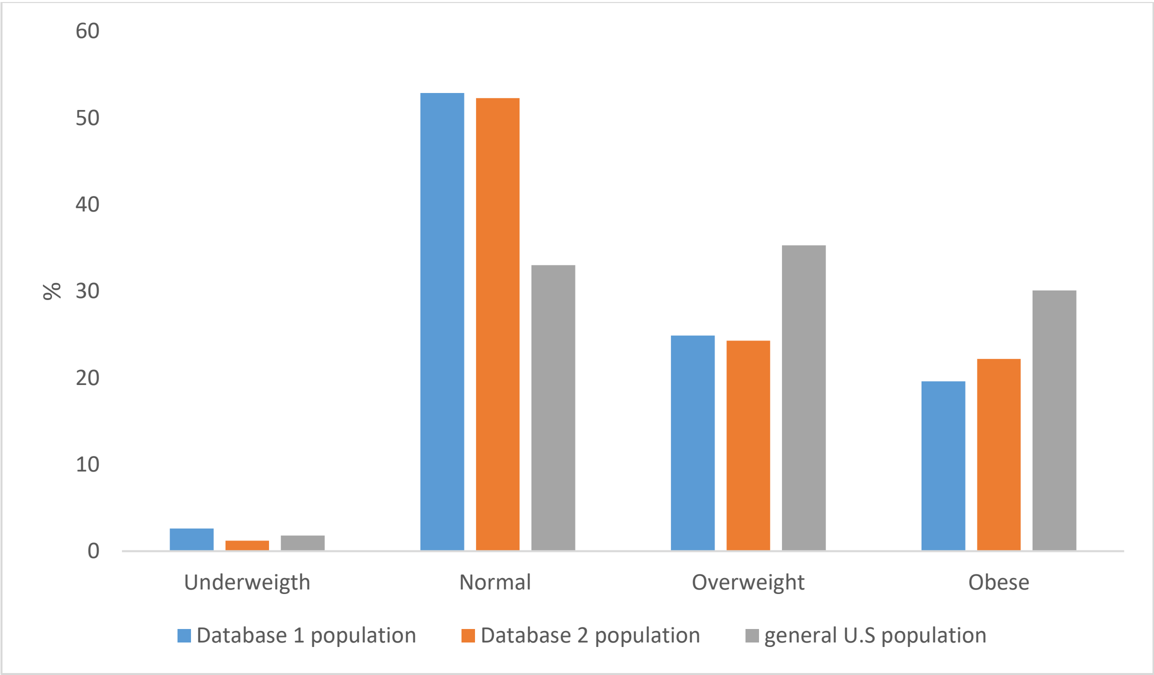


Figure 3.1 The BMI distribution of the survey population and the general U.S. Population (2016)
(Data source: BRFSS Prevalence & Trends Data at Centers for Disease Control and Prevention website: https://www.cdc.gov/brfss/brfssprevalence/)

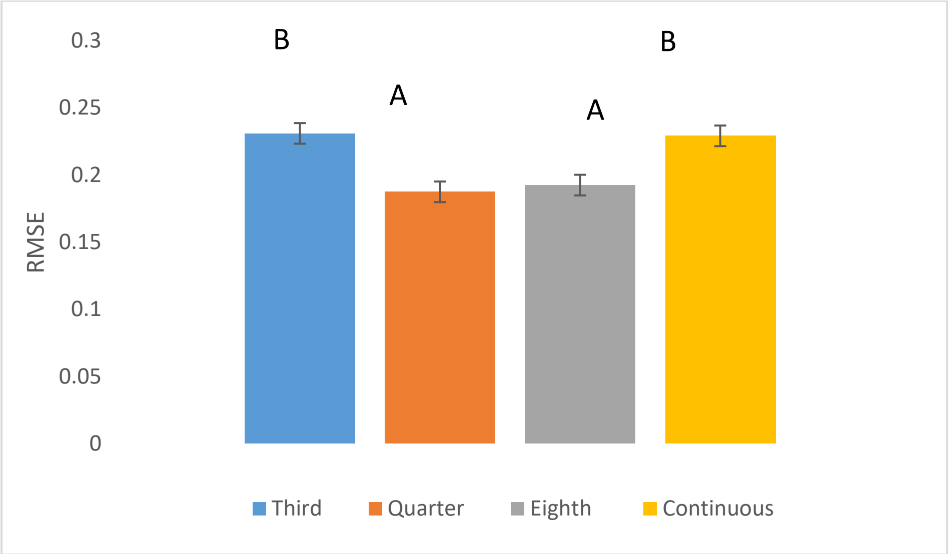


Figure 3.2: Comparison of RMSEs among the Third, Quarter, Eighth, and Continuous Systems. (Non-overlapped letters showed significance level, $p<0.05$. Error bars represent SEM calculated via Oneway Anova)

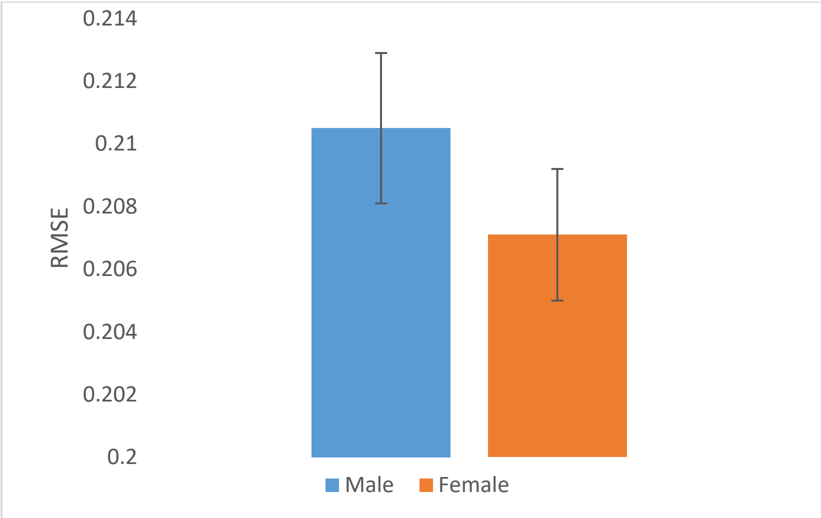
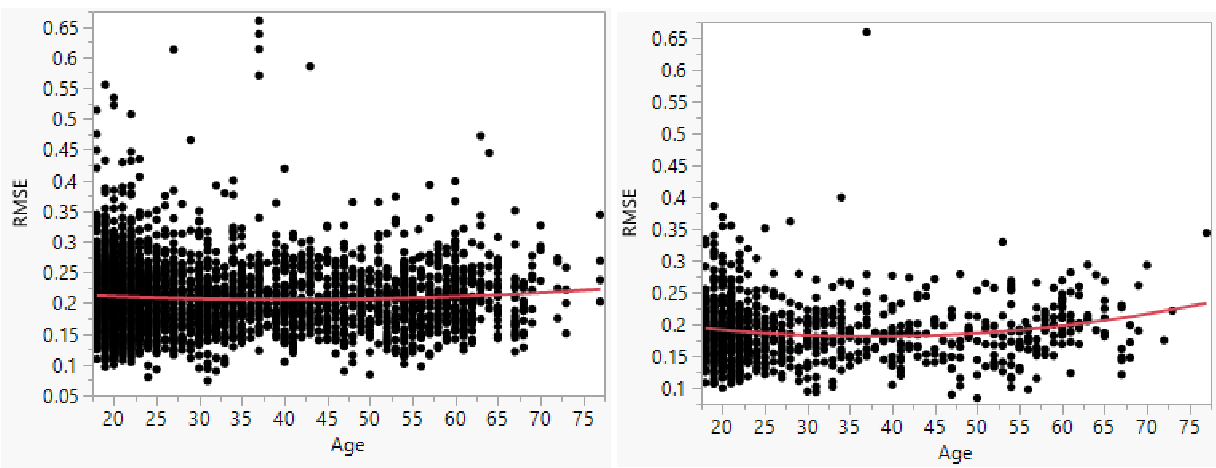


Figure 3.3: Comparison of the overall RMSE (across the four visual estimation systems) between males and females (Error bars represent SEM calculated via Oneway Anova)



A

B

Figure 3.4: Relationship between age and RMSE. A: the overall RMSEs. B: RMSEs in the Quarter system. (Black dot represents each participant's RMSE using one estimation system, red line represents fitting the quadratic polynomial.)

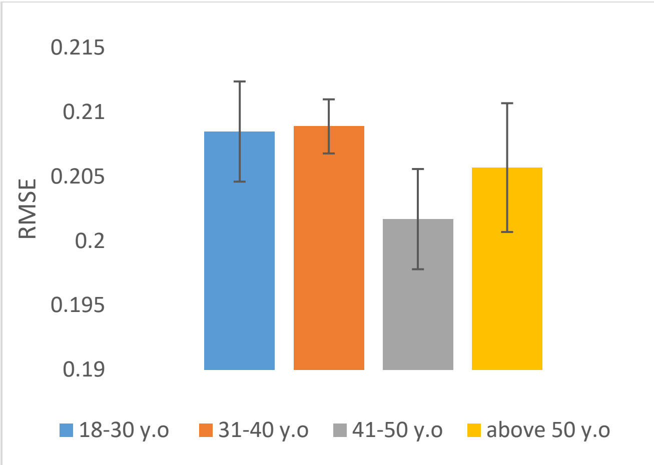


Figure 3.5: Comparison of the overall RMSEs (across the four visual estimation systems) among different age groups. (Error bars represent SEM calculated via Oneway Anova)

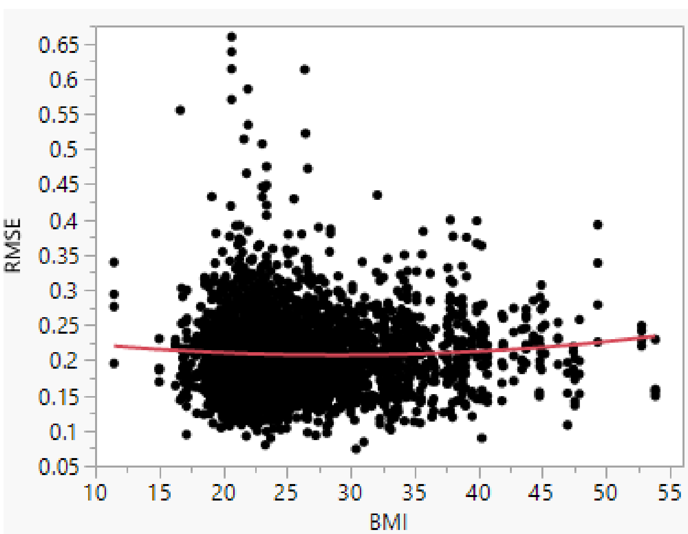


Figure 3.6: Relationship between BMI and RMSE. (Black dot represents each participant's RMSE using one estimation system, red line represents fitting the quadratic polynomial.)

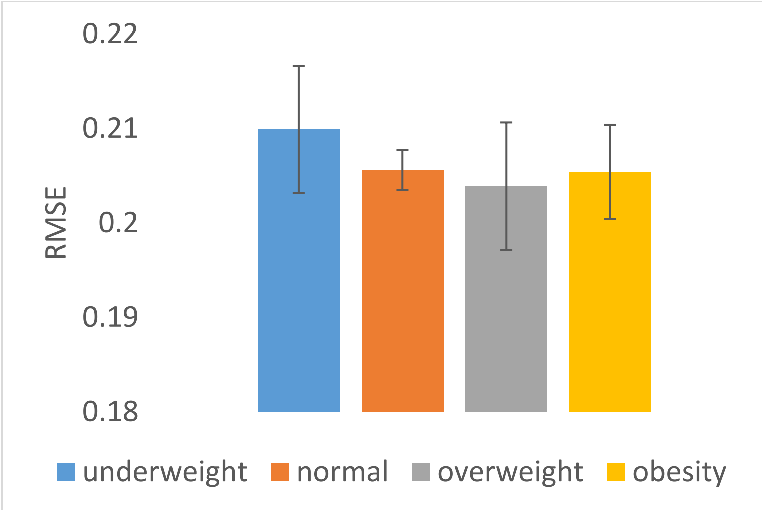


Figure 3.7: Comparison of the overall RMSEs (across the four visual estimation systems) among different BMI categories.

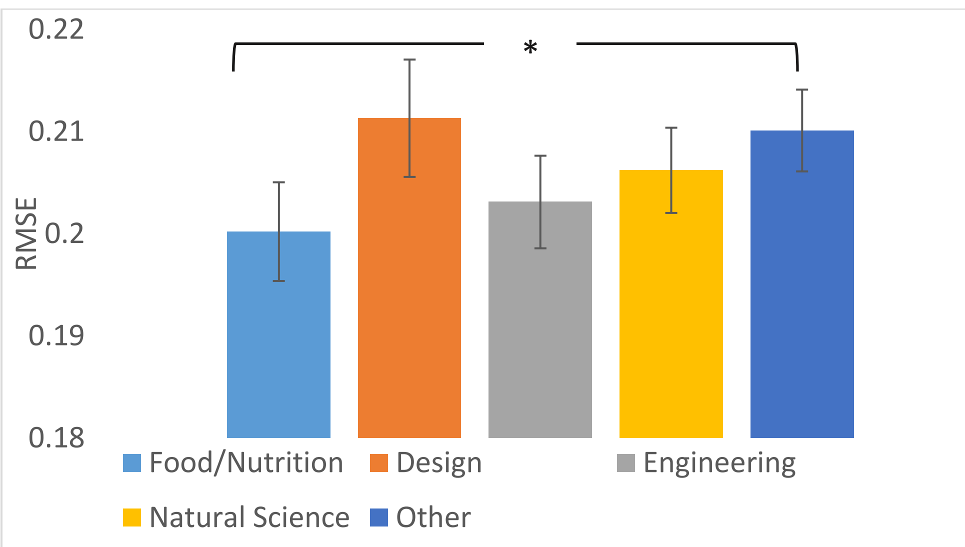
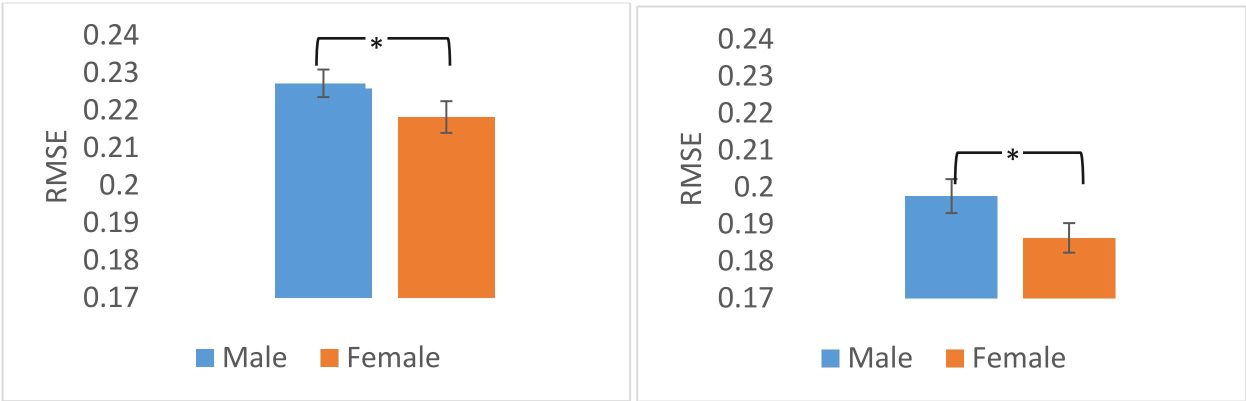


Figure 3.8: Comparison of the overall RMSEs (across the four visual estimation systems) among different major categories.



A B

Figure 3.9: The influence of gender on RMSE in the Third and Quarter systems. A: Third system. B: Quarter system.

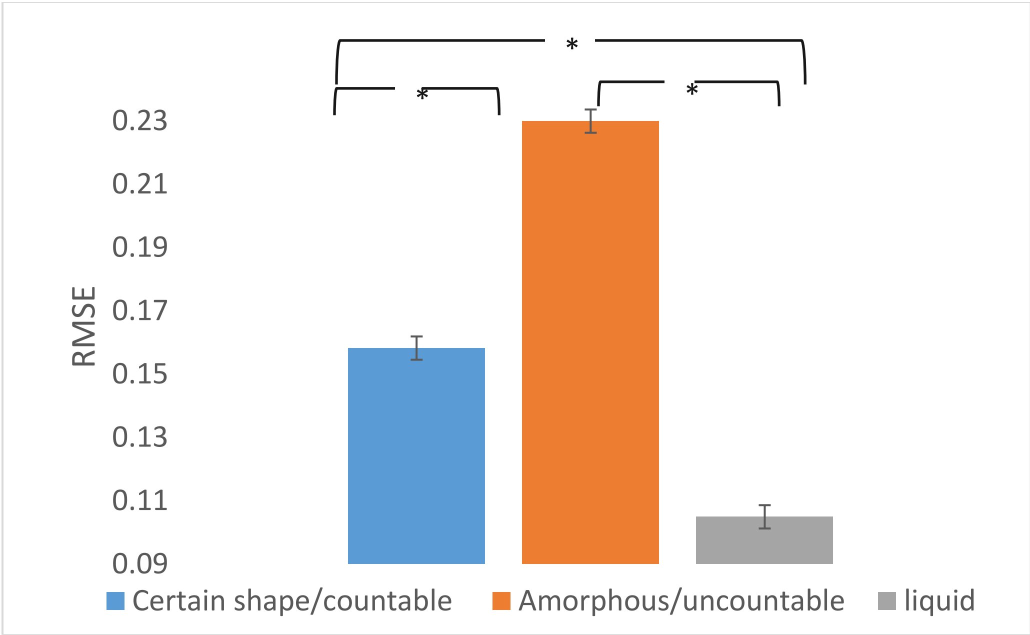
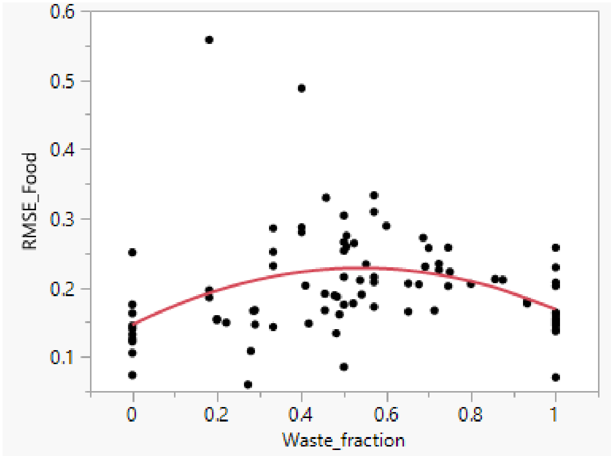
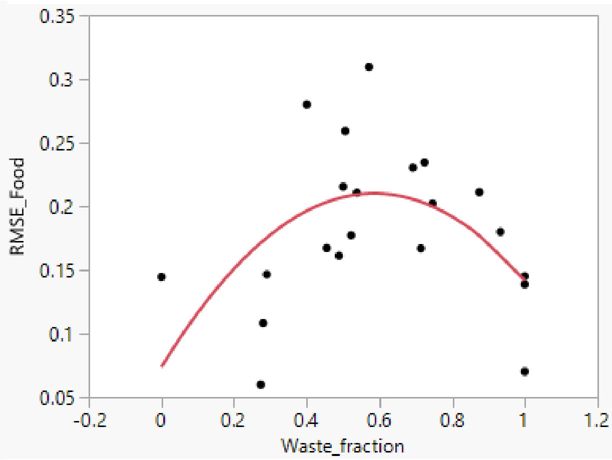


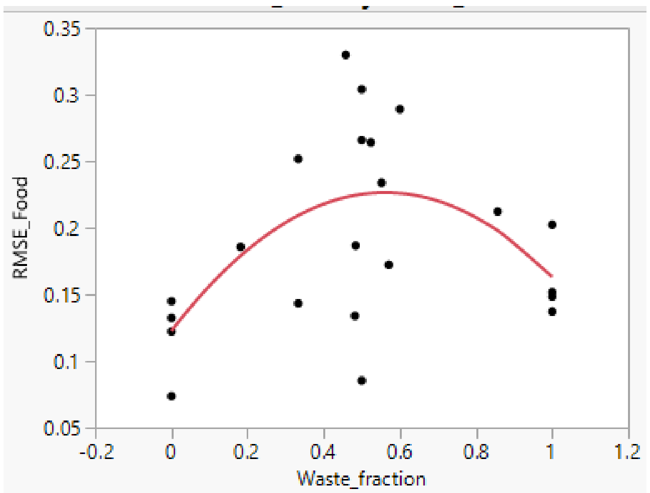
Figure 3.10: Comparison of the overall RMSEs (across the four visual estimation systems) among different food types.



A



B



C

Figure 3.11: Relationship between waste percentage and RMSE. A: the overall RMSEs B: RMSEs in Quarter system. B: RMSEs in Eighth system (Black dot represents the RMSE of each food item estimated by the entire survey population, red line represents fitting the quadratic polynomial.)

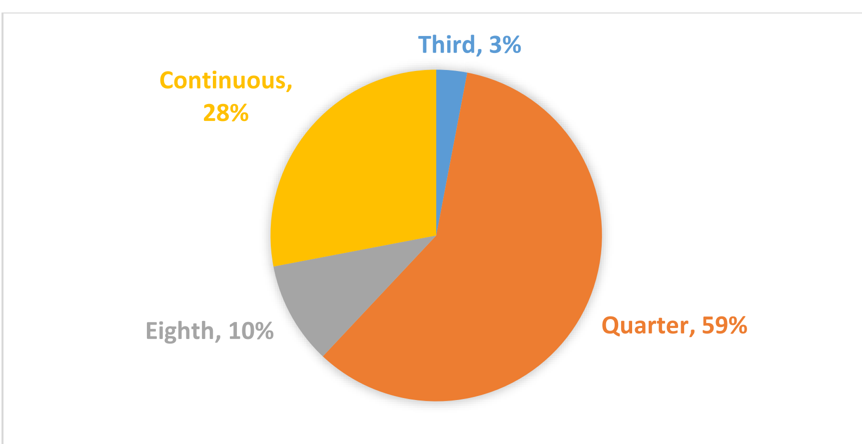


Figure 3.12: The preference of the survey population on using the four visual estimation systems.

CHAPTER 4. UTILIZING A PHOTO-BASED FOOD VISUAL ESTIMATION METHOD TO DETECT THE EFFECTS OF SWITCH PROGRAMMING ON SCHOOL LUNCH CONSUMPTION PATTERNS

Modified from a paper to be submitted to *Journal of Nutrition Education and Behavior*

Yuanying Lou,[1] Huaiqing Wu,[2] Gregory J. Welk,[3] Spyridoula Vazou,[3] Senlin Chen,[4] Douglas A. Gentile,[5] Richard R. Rosenkranz,[6] David A. Dzewaltowski,[7] and Lorraine Lanningham-Foster[1*]

[1]Departiment of Food Science and Human Nutrition, Iowa State University, Ames, IA

[2]Department of Statistics, Iowa State University, Ames, IA

[1]Departiment of Kinesiology, Iowa State University, Ames, IA

[4]School of Kinesiology, Louisiana State University, Baton Rouge, LA

[5]Departiment of Psychology, Iowa State University, Ames, IA

[6]Department of Food, Nutrition, Dietetics, & Health, Kansas State University, Manhattan, KS

[7]Department of Health Promotion, Social & Behavioral Health, University of Nebraska Medical Center & Buffett Early Childhood Institute, Omaha, NE

[*]*Lorraine Lanningham-Foster will be the corresponding author (lmlf@iastate.edu)*

Abstract

Background: Schools provide an ideal setting to promote positive lifestyle behaviors in youth. The SWITCH (School Wellness Integration Targeting Child Health) implementation process is designed to help schools operationalize and improve school wellness initiatives, including nutrition behaviors.

Objective: This study examined the influence of the SWITCH programming process on school lunch consumption and waste, especially fruits and vegetables.

Study Design, Setting, and Participants: Four schools from a suburban school district in Iowa were included in the evaluation: two were participating in SWITCH and two were not. A total of 16 measurements were conducted in SWITCH and control schools on two days before SWITCH started and two days after SWITCH finished. Before- and after-lunch photos were taken for 740 trays from 5th grade students in the four participating schools (n= 362 for SWITCH schools and n=378 for control schools).

Outcomes: Trained research assistants used the 'Quarter System' to compare the before-and after- lunch photos for each student to estimate waste percentage for individual food items on each tray. Based on the initial portion size, fruit and vegetable consumption was calculated. Linear mixed models were applied to analyze the effects of SWITCH, gender, and food types on the waste and consumption patterns.

Results: There was no significant decrease in overall school lunch waste (average percentage wasted across all food types) in both SWITCH and control schools. Further, school lunch waste was not significantly different between SWITCH and control schools at either baseline or endpoint. However, students in SWITCH schools significantly increased their fruit consumption ($p=0.02$) by increasing their initial portion size. Males consumed fewer vegetables than females did ($p<0.0001$). Although males wasted fewer vegetables ($p<0.0001$), they selected much less to start ($p<0.0001$).

Conclusion: By increasing the selection portion size, SWITCH programming may have a positive influence on fruit and vegetable consumption in children.

Introduction

The prevalence of pediatric overweight and obesity increased dramatically over the past 30 years and it has become one of the most challenging public health problems in 21st century.[1,2] In the United States since 1970s, the rate of overweight and obesity in children and adolescents increased over threefold.[2] In the year 2015-2016, the percentage of obesity among U.S youth aged 2-19 years was 18.5%.[3] The increasing pediatric obesity epidemic is of a great concern because children with obesity are at a higher risk of suffering a wide range of co-morbidities.[4,5] Persistence of childhood obesity into adulthood increases the risk of cardiovascular diseases and all-cause mortality.[4] Children with obesity may experience more social isolation and psychological problems, such as low self-esteem and body dissatisfaction, which may lead to poorer achievements and lower family income in later adulthoods.[4,6]

Effective prevention and treatment programs to reverse the pediatric obesity epidemic have been highly demanded and established as a critical priority.[7,8] Considering that children spend most of the day in school, large segments of the youth population could be reached, and parents and families could be involved efficiently, school is commonly the target and can provide an ideal setting for childhood obesity intervention programs.[8,9] In a position paper published by the Academy of Nutrition and Dietetics in 2013, various types of pediatric obesity intervention programs aiming at modifying physical activity, diet, or both, have been systematically evaluated and analyzed.[10] They concluded multicomponent school-based pediatric obesity interventions which include both nutrition education and physical education were the most successful because these programs not only may be effective in improving adiposity measures, but also could improve at least one behavior associated with pediatric overweight and obesity.[10] Previous research has indicated that school environmental changes could provide a positive influence on children's nutrition status and weight management.[11–13]

Designed to support school wellness programming and contribute to youth obesity prevention, SWITCH (School Wellness Integration Targeting Child Health) is a multicomponent, ecologically based intervention focused on improving children's lifestyle behaviors by switching "what they Do, View, and Chew". Instead of targeting and influencing children directly, SWITCH emphasizes the changes happening within physical environments (such as the school and home) and social environments (such as teachers/child and parent/child), thus could be characterized as a structural intervention.[14] Because the interventions in SWITCH involve interactions with the school setting, SWITCH can also be considered a complex intervention.[15] SWITCH has been modified from the original print-based program to online delivery for the broader adoption and implementation purpose.[14–16] A formative evaluation demonstrated the online SWITCH yielded similar results as the original print-based program, which was considered to be a more cost-effective and sustainable method for larger dissemination.[16] Since 2016, SWITCH has focused on supporting schools to become the key delivery agents through modifying factors within physical and social environments to improve youth behaviors.

The logic model of SWITCH is depicted in Appendix F. Changes in school and home, as well as the interactions between parents and children or between teachers and students, all work together to bring the synergistic influence on improving youth behaviors. The key component in the SWITCH program was the development of school modules and school training methods, which empowered the school wellness leaders and established the capacity of schools as being a delivery agent and coordinating center.

Schools receive various resources including posters, trinkets, letters to parents, and guidelines to help them implement the SWITCH program over a 12-week implementation period with weekly Do, View, Chew themes. Three school modules—Classroom, Physical Education (PE), and Lunchroom—were developed in the implementation process. Based on the established "Move for Thought" kit,[16] the Classroom module contains 20 different activities integrating academic concepts as well as the Do, View, and Chew themes. The PE module includes 16 scripted lessons with focus on energy balance. The Lunchroom module provides guides for evaluating the current school cafeteria environment and serving practice, as well as for incorporating key concepts from the Smarter Lunchrooms Movement (SLM) into the lunchrooms of the schools participating in SWITCH. Fruit and vegetable tastings were also conducted in schools to increase the fruit and vegetable consumption.

Based on USDA Smarter Lunchroom recommendations, SWITCH Lunchroom provides resources and strategies for schools to modify their cafeteria environment and improve the lunch quality. Previous research indicated that childhood nutrition and weight regulation could be positively influenced by modifications completed in the school cafeteria environment.[11–13,17,18] The paper published by Blanchette and Brug in 2005 demonstrated multi-component school-based interventions which incorporated classroom, parents, and food service personnel had the largest influence on improving children's fruit and vegetable consumption.[18]

Various dietary assessment methods have been used in measuring children's dietary intake. Self-reported measurements, such as 24-hour diet recall, diet history, and Food Frequency Questionnaire--are commonly used in adult populations.[19,20,21] However, some difficulties might be encountered when these methods are applied in children and adolescents, especially in the context of overweight and obesity.[22,23] Weighing the food is another common method in measuring children's dietary intake. This method has been widely used in school plate waste studies so far.[24] And it is called "the gold standard" because of its high reliability and accuracy.[25] However, it is very time-consuming and labor intensive.[24,26–28] In recent years, the photo-based visual estimation method has drawn more attention due to its easy implementation, cost effectiveness, and high flexibility. [27,29–32] Considering its advantages and the study design, photo-based visual estimation method was chosen to measure the school lunch consumption and waste in this study. The results from our previous study (Chapter 3) indicated that the Quarter system was an accurate as well as well-accepted rating scale used in photo-based visual estimations and therefore it was used in the current study.

The primary aim of this study was to evaluate the effects of SWITCH on students' dietary behaviors, focusing on fruit and vegetable consumption and compared with the recommended meal patterns for school lunches. Our hypothesis was the SWITCH program would provide a positive influence on fruit and vegetable consumption in children.

Methods

Implementation Process of SWITCH

The implementation process of the SWITCH program has been discussed in a separate paper.[33] The SWITCH program lasted 12 consecutive weeks from early February to late April in 2017, and it was implemented in eight total elementary schools across the state of Iowa. Schools participating in SWITCH were required to enroll a team of at least three school wellness members working as the SWITCH coordinators to foster a team approach in the school wellness program. School nurses, classroom teachers, food service directors, and PE teachers were the common types of staff represented on the school teams. Students in 4th and 5th grades were the main target population in this program.

An overall orientation training was provided to each participating school via webinar before the program launch. Defining elements of SWITCH (i.e. Quality Elements) were described in the training, and the schools were instructed about how to use the program materials. During the 12-week program implementation, three checkpoint sessions were conducted to help the schools solve problems, provide students' baseline reports, and facilitate the SWITCH programming process in individual schools. Motivational Interviewing principles were adopted in the checkpoint sessions with the intent to promote autonomy within the schools and empower them to identify strategies and solutions that worked best for them and helped school teams run the program on their own.

A new tool called the *School Wellness Environment Profile* (SWEP) was introduced in the program implementation in 2017 to assist the participating schools in evaluating school wellness environments.[33,34] Students were instructed to track their behaviors using a customized, web-based platform. Teachers had access to the module, curriculum resources, and posters to facilitate the implementation process. However, they also had some freedom to decide how to use these materials to best fit their needs and interests. The posters were hung in the classroom, gym, and cafeteria to reinforce the message delivered through the modules. A Community of Practice platform was established for professional development, sharing of resources, and fostering collaboration to increase the motivation and engagement of school wellness members.

Study Participants

Four elementary schools from a suburban school district in mid-size Midwest community in Iowa participated in this study. Among them, two schools (referred to as SWITCH schools hereafter) participated in the SWITCH program in spring 2017. The other two schools (called control schools) were chosen from the same district and were also matched with the two

SWITCH schools by demographic information available throughout the state department of education website using school total enrollment number and the Free-Reduced Lunch [FRL] percentage. For the purpose of the study and to minimize disruption to the school lunch setting, plate waste measurements were only collected in 5th grade students in all schools.

Prior to the data collection in this study, an approval from the *Institutional Review Board* (IRB) of Iowa State University was obtained (IRB # 14-651, Appendix G). All information collected from students in the SWITCH program was de-identified and therefore obtaining informed consent was waived.

Study Design

Plate waste measurements were conducted on two separate days in each school in February 2017 before program implementation (i.e. baseline data).), as well as after the end of the program in May 2017 (i.e. endpoint data), providing 16 total plate waste measurements.

To reduce the confounding effects on wasted percentage caused by different food items, days for plate waste measurements were selected based on the menu. A cycle menu was shared among the four schools which were in the same school district. All measurement days were selected purposely to keep the menu items comparable and consistent between SWITCH schools and control schools, as well as between the time of baseline and endpoint. The table in Appendix H provides the details about menu items on each measurement day.

Study Procedure

Collection of food waste photos

The photo-based food visual estimation method was adopted in this study to assess the percentage of individual wasted food items on each tray. Protocols about conducting the photo-based plate waste measurements were developed and described in previous research articles.[27,29,30,35] Disposable trays were provided to schools on the measurement days, and each tray was assigned a unique identification number to distinguish schools and students (without being related to any personal information of students). After the students filled their trays with the offered foods (protein, grain) and the selected fresh fruits and vegetables from the salad bar, two research assistants standing at the point of sale took pictures for each student before they were directed to their seats for lunch (i.e. before-photos). Two cameras (Kodak, Pixpro FZ53, Rochester, NY) were used to capture the photos of male's and female's trays separately. Students were instructed to select their own self-identified gender and have the tray picture taken in the corresponding gender line. Prior to the measurements, the research assistants received trainings on how to take photos consistently. Cameras were held right above the tray at a 90° angle. After finishing the meals, students were instructed by the teachers to leave their trays (including all the wastes) on the table. The same research assistants took pictures again for each tray using the same method (i.e. after-photos). Adjustments on some of the trays, such as removing napkins or pouring the uneaten portion out of a package, were made as needed to make sure all food items were visible in the pictures.

Photos processing and visual estimation

All photos were downloaded to a computer in the research team lab. Research assistants paired the before-photo with the after-photo for the same tray according to the identification number. Figure 4.1 shows an example of a paired before- and after-photo for a tray from one of the measurement days. Gender was also identified based on the camera that was used to take the before-photos. The Quarter system was chosen to be used as the rating scale in the visual estimations in this study. For individual food items, the waste was grouped into five categories-none wasted, ¼ wasted, ½ wasted, ¾ wasted and all wasted-by two research assistants who performed the estimation simultaneously. If the two research assistants could not reach an agreement, a third person looked at the picture as the tiebreaker. Prior to the estimations, about 4-6 hours training were provided to the research assistants conducting the estimations. Tests of weighed trays were also conducted to examine the accuracy and interrater reliability of the research assistants. The Root Mean Square Errors (RMSEs) of their estimations compared to the actual weight were less than 0.15, representing high accuracy in the estimations. The correlations between visual estimations and actual weights in the test were also high ($r>0.85$). Using intraclass correlations, agreement between the two research assistants was high ($r= 0.92$).

MyPlate Standard serving sizes for specific fruits/vegetables were used as the reference values (Appendix I). Photos of food with reference values were also taken in order to determine three different values: 1) amount of food selected (selection amount), 2) amount of food which was wasted at the end of lunch (wasted amount), and 3) amount of food which was eaten or consumed during lunch (consumption amount). Following the same procedure for estimating the wasted percentage, the Quarter system was used in estimating the selection percentage of each fruit or vegetable in the before-photos when compared to the photo with the reference value. The selection, waste, and consumption amount were then calculated using the following equations:

*Selection amount (cups equiv.) = selection percentage *reference amount*

*Waste amount (cups equiv.) = wasted percentage * selection amount*

Consumption amount (cups equiv.) = selection amount -waste amount

Data Analysis

For wasted percentage, the mixed-model was used to analyze the intervention effects of SWITCH on school lunch waste. The wasted percentage for each food item on each tray was the response outcome. The intervention arms (SWITCH schools VS control schools), time (baseline

VS endpoint), gender (male VS female), and food types were utilized as fixed effects. There were two levels of experimental units in this model: schools treated as the whole plot level to detect the intervention effects; individuals treated as the sub-plot level to detect the influence from gender and food types.

To detect the program influence on fruit and vegetable consumption in school lunch, the selection, waste, and consumption amounts of fruit, vegetable, and total fruit and vegetable were calculated for every tray on each measurement day. A Total of nine mixed models were established separately using a) fruit selection/waste/consumption, b) vegetable selection/waste/consumption, and c) total fruit and vegetable selection/waste/consumption as the response outcome, respectively. In each model, intervention arms, time, gender were the predicting variables.

Pairwise comparisons were conducted using least square adjusted means between different levels of one predicting variable either at the specific level of the other variables, or averaged over the other factors. Tukey adjustment was used in each pair comparison, and the adjusted p values are reported.

Milk waste was not collected at the individual level, but at the whole school level. The total wasted amount for each type of milk was measured. Fat –free Chocolate milk, skim milk, and strawberry milk were provided during the school lunch on each day. The selection percentage, the average consumption volume (ml) per person, and the wasted percentage was calculated for each milk type using the following equations:

$$\textit{Selection percentage for a specific milk type} = \frac{\textit{number of students selecting a specific milk type}}{\textit{total number of students}} *100$$

$$\textit{Average consumption volume/person (ml)} = \frac{\textit{total number of specific milk type cartons selected}*236ml}{\textit{number of students selecting the spefici milk type}}$$

$$Wasted\ percentage\ for\ a\ specific\ milk\ type = \frac{total\ wasted\ volume\ (ml)}{total\ number\ of\ specific\ milk\ type\ cartons\ selected * 236ml} * 100$$

Comparisons among different milk types in SWITCH schools and control schools at either baseline or endpoint were conducted.

All statistical analysis was performed using Statistical Analysis Software 9.4 (SAS Institute, Cary, NC). The statistical significance was set as $p \leq 0.05$.

Results

Descriptive Characteristics of Study Participants

The descriptive characteristics of the schools participating in this study are presented in Table 4.1. The four schools were from the same school district with the major race being white. To make the dietary analysis results more comparable between the two school categories (i.e. SWITCH and control schools), control schools were chosen according to the student enrollments and other school characteristics comparable to SWITCH schools. Control school 1 was comparable to SWITCH school 1 with a larger enrollment number and lower FRL percentage; however, control school 2, which had a smaller enrollment number and higher FRL percentage, was comparable to SWITCH school 2. The average daily NSLP participants in 5th grade over the four schools was 46.3, and there was no significant difference between SWITCH schools and control schools. There was no significant difference between the participation of male and female in NSLP in SWITCH and control schools, and there was no time effect on male or female's participation in NSLP. Photos were collected for 740 total trays over the 16 measurements.

Food Wasted Percentage

Overall food wasted percentage

An average of 28.71% of total food was wasted per school lunch (95% CI = 27.18 % to 30.24%). There was no significant difference between SWITCH and control schools, either at baseline or endpoint (p= 0.96 and 0.19, respectively). There was also no significant difference between baseline and endpoint in either SWITCH schools or control schools (p= 0.81 and 0.11, respectively). Table 4.2 shows the overall food wasted percentage, calculated in SWITCH and control schools at baseline and endpoint.

Comparison of food wasted percentages among different categories

Over the 16 plate waste measurement days, there were 24 total different types of food provided in the school lunches. The mean wasted percentage of each food over all measurements is presented in Appendix J in the order of the wasted percentage from the highest waste to the lowest waste. The 24 foods were divided into five categories to be compared: hot entrée, cold entrée, cooked vegetable, fresh vegetable, and fruit. Hot entrée and cold entrée contain grain and protein foods defined in MyPlate; fruits and vegetables were classified based on MyPlate standards. Vegetables were further divided into cooked vegetables and fresh vegetables based on their preparation and serving style: cooked vegetables were cooked and served by school cafeteria personnel together with entrée; however, fresh vegetables were raw and self-served in the school salad bar together with fruits. The classifications of individual foods into specific categories is also presented in Appendix J. The comparison of food wasted percentage among the five food categories is shown in Figure 4.2. The range of the wasted percentage is from 12.39% to 43.79%. Hot entrée had the lowest wasted percentage with the estimated mean of 12.39% (Standard Error of the Mean (SEM) = 1.82%), significantly lower than any of the other four categories (p<0.001 for each pair comparison). Following hot entrée, the categories with wasted percentage from low to high were cold entrée, cooked vegetable, fresh vegetable, and fruit. However, there was no significant difference in all pair-wise comparisons among the four categories. Among the 20 pair-wise comparisons of each food category, fresh vegetable had significantly higher wasted percentage at endpoint than baseline in SWITCH schools (Table 4.3).

Fruit and Vegetable Selection, Waste, and Consumption Pattern

Total fruit and vegetable selection, waste, and consumption

Each fruit, fresh vegetable and cooked vegetable item on individual food trays was estimated for the selection percentage compared to the reference value, and then selection, waste and consumption amount were calculated, respectively. The selection/waste/consumption values of all the fruits and vegetables contained on that plate were combined to obtain the total fruit and vegetable values. Comparisons were performed between SWITCH and control schools, between baseline and endpoint, and between male and female (Figure 4.3). At baseline, total fruit and vegetable selection amount in control schools was significantly higher than SWITCH schools (mean = 1.23 and 1.07 cups equiv., respectively, p=0.02), however, the significant difference between the two groups disappeared at the endpoint with the mean of 1.15 for control schools and 1.22 for SWITCH schools. In control schools, there was no significant difference between baseline and endpoint (p=0.51); while in SWITCH schools, the total fruit and vegetable selection significantly increased from baseline to the endpoint (p=0.03). Performing the same pairs of comparisons in waste amount as with selection amount, the results indicated there was no significant difference in any of the comparisons. Therefore, the differences in consumption directly resulted from the difference in selection amounts as supported by the data. Figure 4.3 B shows the consumption pattern of total fruit and vegetable and it indicates the similar pattern as observed in selection. Although the consumption increase in SWITCH schools from baseline to endpoint was not significant, it was approaching significance (mean = 0.58 and 0.71 cups equiv., respectively, p=0.06). Figure 4.3 C indicates the females consumed fruits and vegetables significantly higher than males (mean =0.70 and 0.60 cups equiv., respectively p=0.01).

Fruit selection, waste, and consumption

To fully understand the fruit and vegetable consumption pattern, it was necessary to study the fruit and vegetable consumption separately. Similar procedures were performed in calculating fruit selection, waste, and consumption as with total fruit and vegetable, but only included the amount of fruit as the dependent variable. At baseline, the amount of fruit selection was significantly lower in SWITCH schools compared to control schools being 0.77 and 0.97, respectively, p=0.001. Figure 4.4 A shows clearly that the fruit selection increased in SWITCH schools whereas it decreased in control schools. Although such increase or decrease was not significant, at endpoint, there was no significant difference between SWITCH and control schools (mean =0.85 and 0.85 cups equiv., respectively). Fruit consumption pattern was similar as selection pattern (Figure 4.4 B). At baseline, the amount of fruit consumption in SWITCH schools was significantly lower than control schools (mean = 0.37 and 0.51 cups equiv., respectively, p=0.004). However, the SWITCH program significantly increased the fruit consumption (p=0.02). Therefore, at endpoint there was no significant difference between SWITCH schools and control schools (mean = 0.5 and 0.46 cups equiv., respectively, p=0.87). Fruit consumption in SWITCH schools at endpoint met the 2010 IOM recommendations for fruit offered during school lunch, which was 0.5 cups equiv. per day. Males selected more fruits than females (mean = 0.91 and 0.81 cups equiv., respectively, p=0.004, Figure 4.3 C), however, they also wasted more (mean = 0.45 and 0.35 cups equiv., respectively, p=0.005, and Figure 4.4 D).

Combining the selection together with the waste, the overall fruit consumption was similar in males and females (mean = 0.47 and 0.46 cups equiv., respectively, p=0.70).

Vegetable selection, waste, and consumption

Figure 4.5 A and B shows the amount of vegetable selection and consumption in SWITCH and control schools at baseline and endpoint. The patterns of selection and consumption were the same: there was a slight increase of vegetable selection observed in both SWITCH and control schools from baseline to endpoint, however, such increases were not significant (p= 0.26 and 0.62, respectively), thus the consumption remained almost the same from baseline to endpoint. The amount of vegetable consumption in SWITCH and control schools at endpoint was 0.37 and 0.31 cups equiv., respectively, and there was no significant difference between the two. Vegetable selection, waste and consumption patterns were consistent among males and females: males consumed less vegetable than females did (Figure 4.5 E, p<0.001). Although males wasted less (mean = 0.09 and 0.14 cups equiv., p<0.001, Figure 4.5 D), they selected much less to start (mean = 0.23 and 0.39 cups equiv., p<0.001, Figure 4.5 C). None of the schools met the 2010 IOM recommendation for vegetable, i.e. 0.75 cups equiv. per day, at either baseline or endpoint.

Whole Fruit VS Sliced Fruit

For the same food, changing the preparation method may have an impact on the wasted percentage and consumption. Among the 16 measurements, whole apples were provided on 14 days while sliced apples were only provided on the other two days; similarly, whole oranges were provided on 13 days while sliced oranges were provided only on one day (there were two days where oranges were not served). Figure 4.6 A showed there was a significant difference of wasted percentages between whole apples and sliced apples (mean wasted percentage = 60 %

and 23% , respectively, $p<0.001$). As to the orange, although the wasted percentage of sliced orange was lower than whole orange, the difference was not significant (mean wasted percentage = 59.4% and 37.5%, respectively, $p=0.25$). For apples, using the method of pre-slicing didn't increase the selection ($p=0.27$), however, it did decrease the waste significantly ($p=0.001$). Therefore, the consumption increased significantly ($p<0.001$, Figure 4.6 B).The amount of orange consumption also increased significantly after slicing them ($p<0.001$, Figure 4.6 B), however, different from the patterns observed in apples, this increase of orange consumption resulted from significant increase in its selection ($p<0.001$, Figure 4.6 B).

Milk Selection, Waste and Consumption

The school category and the SWITCH program did not have a significant influence on the milk selection, waste, and consumption, however, the milk types did. Figure 4.7 A shows that about 78.6% students chose chocolate milk during their school lunch, significantly higher than the skim milk and strawberry milk selections (14.1 % and 7.1 %, respectively). However, there was no significant difference among the three milk types in average consumption volume per person and the wasted percentage (Figure 4.7 B and C). Over the three milk types, an average of 146.65 ml was consumed by each student (SEM = 8.11ml); the total wasted percentage was 29.58% (SEM = 2.46%).

Discussion

SWITCH is designed to improve children's overall health by improving their healthy lifestyle behaviors: increasing fruit and vegetable consumption, increasing physical activity, and decreasing screen time.[36] Schools provide an ideal setting to connect students, parents and teachers as well as increase their engagement in childhood obesity interventions. In SWITCH, the lunchroom, classroom and PE classes work together to provide consistent messages, helping students cultivate healthy lifestyle behaviors including nutrition, physical activity, and screen time. Therefore, the primary objective of this study is to evaluate the impact of SWITCH programming on school lunch waste and consumption patterns.

The results in this study showed the total wasted percentage of a school lunch averaging over 16 measurements in four participating schools was 28.71%, which was consistent with a previous study reporting more than a third of vegetable, fruit and grain items were wasted in elementary school lunches.[37] The SWITCH programming did not have a significant influence on decreasing the total wasted percentage from baseline to endpoint. Compared to the decrease observed in control schools, there was a slight increase in wasted percentage in SWITCH schools (not statistically significant, p= 0.96, Table 2). This result was not very surprising, because the primary goal of SWITCH is focused on increasing the students' fruit and vegetable consumption, not decrease the waste of these foods. The increase in selection amount resulted in an increase in consumption regardless of the waste.

Food waste varies among different food types, as demonstrated in previous research.[38] Similar patterns were observed in this study. Hot entrée had the lowest wasted percentage among the five categories; contrarily, fruits and vegetables wasted much more. Measured in a USDA report, wasted percentage of cooked vegetables, fresh vegetables, and fresh fruits was 42%, 30%, and 22%, respectively[39]. Our findings are comparable to this report, except for the fruit, which was estimated to be 43.79% in our study. One possible explanation for this is that the average wasted percentage of fruit can be influenced by the degree of ripeness or quality which ultimately influences the fruits flavor, texture, and likability. For example, the kiwi fruit was provided in one school for only one day. The waste (82%) was very high because it was not ripe.

It was nearly impossible to eat because it was very hard in texture. When serving fruits and vegetables, seasonality of that product should be taken into consideration.

The wasted percentage of specific foods provided valuable information for understanding the students' consumption in school lunch. For the foods with standard initial portion size and served by school cafeteria personnel, such as hot entrée, cold entrée and cooked vegetables, more waste directly led to less consumption. However, it became much more complicated when calculating the consumption of self-served fruits and fresh vegetables. In the four schools participating in this study, there were some challenges regarding the salad bar. In schools providing the salad bar, students had the freedom to select their own fruit and vegetable items, and previous research showed a positive relationship between the variety of fruits and vegetables presented in salad bars and consumptions.[40–42] However, under this situation (students serving themselves), the initial portion size or selection amount, could vary largely by individual. To have a better understanding of the students' consumption of fruits and vegetables, it is necessary to know their selection amounts.

Total fruit and vegetable consumption largely increased from baseline to endpoint in SWITCH schools, mainly related to the increased selection (Figure 2. A and B). Further analysis revealed that in SWITCH schools the increase in fruit selection led to the increase in fruit consumption, which ultimately contributed to the increase in total fruit and vegetable consumption (Figure 4. A and B). Fruit consumption in SWITCH schools at endpoint met the 2010 IOM recommendations for school lunch offered; however, the vegetable consumption in all four schools, regardless of the time, was much lower than the IOM recommendations.

Gender differences in fruit and vegetable consumption has been widely studied in the literature and we also looked at this factor in the present study. In a review article, gender effect on fruit and vegetable intake in children and adolescents was systematically studied in a total of 49 research papers. Among them, 27 studies reported that females tend to have higher fruit and vegetable consumption; 18 papers found no difference between males and females; 8 observed that males had higher intake than females [43]. In our study, a difference between males and females was also identified, especially for vegetable consumption. Males selected much less vegetables than females. Although males wasted less, their overall vegetable consumption was still lower. Our finding is consistent with previous research, which reported females had a higher level of liking for vegetables and preference for a variety of vegetables due to their lower levels of perceived barriers.[44] The lower selection of vegetables in by males may be related to perceived barriers of vegetable intake. However in this study we did not assess students' perceptions. This piece of information is beneficial to future intervention programs targeting vegetable consumption. More research is needed to understand children's perceptions and values concerning vegetable intake.

How the food is prepared and presented could be a potential factor influencing waste and consumption.[45,46] Our data clearly showed there was an increase in the consumption of sliced fruits compared to whole fruits. Further analyzing the data indicated the increase in consumption may have been related to reducing the waste, which was observed in sliced apples, or may have been related to increasing the selection amount, which was observed in sliced oranges. No matter what reasons cause the consumption increase, the benefits of slicing some fruit or vegetable items could be considered a potential effective strategy to increase fruit or vegetable consumption.

The final area of the school lunch which was explored through plate waste measurement was milk consumption. The School Nutrition Dietary Assessment Study-III revealed more than two thirds of the students who participated in the NSLP chose chocolate milk over white milk.[47] The results in this study showed a similar selection pattern. About 85.62 % of students chose flavored milk (including non-fat chocolate milk and strawberry milk), and only 14.12% chose plain non-fat milk. Among the three types, chocolate milk selection was the highest (mean = 78.57%, SEM= 1.602). The sugar content in chocolate milk can be twice as much as in white milk, thus some school districts have considered limiting or banning the sale of chocolate milk in school meals. However, there were some concerns about the potential negative effects of this banning, such as decreasing the total milk consumption, increasing milk waste, and even decreasing the participation rate in NSLP.[48] Our data indicated there was no significant difference among the three types of milk in waste percentage or average consumption volume per person. In other words, once a student chose one type of milk, they consumed the similar volume regardless of the milk type (Figure 6.B and C). This provided support for one of the recommendations in the SWITCH Lunchroom module: move the white milk cartons in front of chocolate milk cartons to make them easier to be accessed by students. This study suggests that there is less concern about the waste increasing once students change to consuming white milk. On the contrary, schools should focus on finding creative ways to increase the white milk selection by making it more attractive and accessible.

Previous research indicated that SWITCH could generate small to modest implementation effects on increasing the consumption of fruits and vegetables and decreasing the screen time in children.[36] In that study, the fruit and vegetable consumption was self-reported by children together with their parents. The self-report dietary assessments were showed by previous research to be prone to bias or misreporting when applied in children and adolescents.[49,50] In this study, the photo-based food visual estimation method, which was developed and applied widely in other various school-based studies,[13,24,27,29,51–54] was selected to estimate wasted percentage for individual food items on each tray. Compared to the on-site visual estimations, the digital photography method has been shown to have many additional benefits and strengths including increasing the efficiency of collecting data, increasing the flexibility, and decreasing disturbance of the lunch.[55] This method is particularly beneficial and well-applied in our study, because the four participating schools all provided a salad bar to allow the students to choose fruits and vegetables themselves, resulting in the selection amounts varying among students. The on-site visual estimation method is challenging for our study because it is impossible for estimators to know and remember every student's initial selection portion size and then estimate the wasted percentage at the end of lunch. However, by taking before- and after- photo for the same tray and paring them based on the assigned unique identification number, the photo-based visual estimation method makes the visual estimations easier and convenient along with high validity and reliability.[31,56] The Quarter system was chosen as the rating scale in the visual estimations in this study, and its reliability and validity have been studied in previously.[54,24] One of our previous studies also provided the support showing the Quarter system had the lowest Root Mean Square Error (RMSE) compared to the Third/Eighth/Continuous systems (unpublished data, Chapter 3).

This study showed the positive impact of SWITCH programming on increasing children's fruit and vegetable consumption, providing evidential support to further extend SWITCH programming and dissemination. However, some limitations existed with our study. First, according to the IRB determinations, all data were de-identified, meaning any information related to knowing students' identity was not collected. Therefore, we could not pair the diet data for the same student at different time points (i.e. baseline and endpoint). This may lead to a higher error term resulting from random differences among individuals. In the future, if the data for one student at different times could be compared, the sensitivity of detecting the program effects may increase. Second, we only measured the students' eating behaviors in school lunches, without knowing their total diet intake over a day. SWITCH programming contains not only the SWITCH Lunchroom module, which focuses on improving school cafeteria environment, but also the SWITCH Classroom and PE modules and other resources to provide messages and education promoting the lifestyle behaviors of students. Therefore, the changes in total diet intake may better represent the effect of SWITCH, not limited to the school lunch setting. Finally, while the overall goal was to increase fruit and vegetable selection for students participating in SWITCH, we recognize that the increases in fruit and vegetable selection lead to increases in food waste. In future programming related to SWITCH Lunchroom, content related to minimizing food waste (along with increasing consumption) will be incorporated.

Conclusions

Data in this study revealed that participation in the SWITCH program might increase students' total fruit and vegetable selection, potentially leading to consumption increases. Such evidence provides support for further extending SWITCH programming, which has been shown to be a promising school wellness initiative targeted at promoting children's healthy behaviors. Further research is warranted in order to strengthen these conclusions.

Acknowledgements

This work was supported in part by the United States Department of Agriculture National Institute of Food and Agriculture (NIFA) grant 2014-08390 "Dissemination of the evidence-based SWITCH program for childhood obesity prevention." This work is solely the responsibility of the authors and does not necessarily represent the views of the USDA.

Authors' Contributions

YL and LLF contributed to the study design. GJW, SV, SC, DAG, RRR, DAD, and LLF contributed to the development and implementing SWITCH. YL and LLF collected the data. YL and HW analyzed the data. YL drafted the first manuscript with the contributions from LLF. All authors reviewed and commented on subsequent drafts of the manuscript

Author Disclosure Statement

No competing financial interests exist.

References

1. UNICEF, WHO, World Bank Group. *LEVELS AND TRENDS IN CHILD MALNUTRITION 156 MILLION*.; 2016. http://www.who.int/nutgrowthdb/jme_brochure2016.pdf. Accessed March 20, 2018.

2. Fryar CD, Carroll MD, Ogden CL. Prevalence of Overweight and Obesity Among Children and Adolescents: United States, 1963–1965 Through 2011–2012. *Natl Heal Nutr Exam Surv*. 2012. https://www.cdc.gov/nchs/data/hestat/obesity_child_11_12/obesity_child_11_12.pdf. Accessed March 20, 2018.

3. Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of Obesity Among Adults and Youth: United States, 2015–2016 Key findings Data from the National Health and Nutrition Examination Survey. *NCHS Data Brief*. 2017;(288):1-8. https://www.cdc.gov/nchs/data/databriefs/db288.pdf. Accessed March 20, 2018.

4. Must A, Strauss R. Risks and consequences of childhood and adolescent obesity. *Int J Obes*. 1999;23(S2):S2-S11. doi:10.1038/sj.ijo.0800852.

5. Deckelbaum RJ, Williams CL. Childhood Obesity: The Health Issue. *Obes Res*. 2001;9(S11):239S-243S. doi:10.1038/oby.2001.125.

6. Gortmaker SL, Must A, Perrin JM, Sobol AM, Dietz WH. Social and Economic Consequences of Overweight in Adolescence and Young Adulthood. *N Engl J Med*. 1993;329(14):1008-1012. doi:10.1056/NEJM199309303291406.

7. Koplan JP, Liverman CT, Kraak VI, Committee on Prevention of Obesity in Children and Youth. Preventing childhood obesity: health in the balance: executive summary. *J Am Diet Assoc*. 2005;105(1):131-138. doi:10.1016/j.jada.2004.11.023.

8. Krebs NF, Jacobson MS, American Academy of Pediatrics Committee on Nutrition. Prevention of pediatric overweight and obesity. *Pediatrics*. 2003;112(2):424-430. doi:10.1542/PEDS.112.2.424.

9. Guidelines for School and Community Programs to Promote Lifelong Physical Activity Among Young People. *J Sch Health*. 1997;67(6):202-219. doi:10.1111/j.1746-1561.1997.tb06307.x.

10. Hoelscher DM, Kirk S, Ritchie L, Cunningham-Sabo L. Position of the Academy of Nutrition and Dietetics: Interventions for the Prevention and Treatment of Pediatric Overweight and Obesity. *J Acad Nutr Diet*. 2013;113(10):1375-1394. doi:10.1016/j.jand.2013.08.004.

11. Williamson DA, Champagne CM, Harsha DW, et al. Effect of an Environmental School-Based Obesity Prevention Program on Changes in Body Fat and Body Weight: A Randomized Trial. *Obesity*. 2012;20(8):1653-1661. doi:10.1038/oby.2012.60.

12. Williamson DA, Copeland AL, Anton SD, et al. Wise Mind Project: A School-based Environmental Approach for Preventing Weight Gain in Children*. *Obesity*. 2007;15(4):906-917. doi:10.1038/oby.2007.597.

13. Williamson DA, Han H, Johnson WD, Martin CK, Newton RL. Modification of the school cafeteria environment can impact childhood nutrition. Results from the Wise Mind and LA Health studies. *Appetite*. 2013;61:77-84. doi:10.1016/j.appet.2012.11.002.

14. Blankenship KM, Friedman SR, Dworkin S, Mantell JE. Structural Interventions: Concepts, Challenges and Opportunities for Research. *J Urban Heal*. 2006;83(1):59-72. doi:10.1007/s11524-005-9007-4.

15. Hawe P, Shiell A, Riley T. Theorising Interventions as Events in Systems. *Am J Community Psychol*. 2009;43(3-4):267-276. doi:10.1007/s10464-009-9229-9.

16. Webster CA, Russ L, Vazou S, Goh TL, Erwin H. Integrating movement in academic classrooms: understanding, applying and advancing the knowledge base. *Obes Rev*. 2015;16(8):691-701. doi:10.1111/obr.12285.

17. Williamson DA, Champagne CM, Harsha D, et al. Louisiana (LA) Health: Design and methods for a childhood obesity prevention program in rural schools. *Contemp Clin Trials*. 2008;29(5):783-795. doi:10.1016/j.cct.2008.03.004.

18. Blanchette L, Brug J. Determinants of fruit and vegetable consumption among 6-12-year-old children and effective interventions to increase consumption. *J Hum Nutr Diet*. 2005;18(6):431-443. doi:10.1111/j.1365-277X.2005.00648.x.

19. Bingham SA, Gill C, Welch A, et al. Comparison of dietary assessment methods in nutritional epidemiology: weighed records v. 24 h recalls, food-frequency questionnaires and estimated-diet records. *Br J Nutr*. 1994;72(4):619. doi:10.1079/BJN19940064.

20. Howat PM, Mohan R, Champagne C, Monlezun C, Wozniak P, Bray GA. Validity and reliability of reported dietary intake data. *J Am Diet Assoc*. 1994;94(2):169-173. doi:10.1016/0002-8223(94)90242-9.

21. Hock K, Tallman D, Kaur D, Mat Daud Z, Khosla P, Karupaiah T. Dietary assessment methods. *J Ren Nutr Metab*. 2018;3(1):8. doi:10.4103/2395-1540.232539.

22. Magarey A, Watson J, Golley RK, et al. Assessing dietary intake in children and adolescents: Considerations and recommendations for obesity research. *Int J Pediatr Obes*. 2011;6(1):2-11. doi:10.3109/17477161003728469.

23. Collins CE, Watson J, Burrows T. Measuring dietary intake in children and adolescents in the context of overweight and obesity. *Int J Obes*. 2010;34(7):1103-1115. doi:10.1038/ijo.2009.241.

24. Hanks AS, Wansink B, Just DR. Reliability and accuracy of real-time visualization techniques for measuring school cafeteria tray waste: validating the quarter-waste method. *J Acad Nutr Diet*. 2014;114(3):470-474. doi:10.1016/j.jand.2013.08.013.

25. Byker Shanks C, Banna J, Serrano EL. Food Waste in the National School Lunch Program 1978-2015: A Systematic Review. *J Acad Nutr Diet*. 2017;117(11):1792-1807. doi:10.1016/j.jand.2017.06.008.

26. Comstock EM, St Pierre RG, Mackiernan YD. Measuring individual plate waste in school lunches. Visual estimation and children's ratings vs. actual weighing of plate waste. *J Am Diet Assoc*. 1981;79(3):290-296. http://www.ncbi.nlm.nih.gov/pubmed/7264115. Accessed January 15, 2018.

27. Williamson DA, Allen HR, Martin PD, Alfonso AJ, Gerald B, Hunt A. Comparison of digital photography to weighed and visual estimation of portion sizes. *J Am Diet Assoc*. 2003;103(9):1139-1145. doi:10.1016/S0002-8223(03)00974-X.

28. Kirks BA, Wolff HK. A comparison of methods for plate waste determinations. *J Am Diet Assoc*. 1985;85(3):328-331. http://www.ncbi.nlm.nih.gov/pubmed/3973322. Accessed January 19, 2018.

29. Williamson DA, Allen HR, Martin PD, Alfonso A, Gerald B, Hunt A. Digital photography: A new method for estimating food intake in cafeteria settings. *Eat Weight Disord - Stud Anorexia, Bulim Obes*. 2004;9(1):24-28. doi:10.1007/BF03325041.

30. Swanson M. Digital Photography as a Tool to Measure School Cafeteria Consumption. *J Sch Health*. 2008;78(8):432-437. doi:10.1111/j.1746-1561.2008.00326.x.

31. Taylor JC, Yon BA, Johnson RK. Reliability and Validity of Digital Imaging as a Measure of Schoolchildren's Fruit and Vegetable Consumption. *J Acad Nutr Diet*. 2014;114(9):1359-1366. doi:10.1016/j.jand.2014.02.029.

32. Stumbo PJ. New technology in dietary assessment: a review of digital methods in improving food record accuracy. 2018. doi:10.1017/S0029665112002911.

33. Chen S, Dzewaltowski DA, Rosenkranz RR, et al. Feasibility study of the SWITCH implementation process for enhancing school wellness. doi:10.1186/s12889-018-6024-2.

34. Lee, J. A., Vazou, S., Ellingson, L., Lanningham-Foster, L., Dixon, P., and Welk GJ. Development and application of tools to assess elementary school wellness environments and readiness for wellness change. 2018.

35. Olafsdottir AS, Hörnell A, Hedelin M, Waling M, Gunnarsdottir I, Olsson C. Development and Validation of a Photographic Method to Use for Dietary Assessment in School Settings. Portero-Otin M, ed. *PLoS One*. 2016;11(10):e0163970. doi:10.1371/journal.pone.0163970.

36. Gentile DA, Welk G, Eisenmann JC, et al. Evaluation of a multiple ecological level child obesity prevention program: Switch®what you Do, View, and Chew. *BMC Med*. 2009;7(1):49. doi:10.1186/1741-7015-7-49.

37. Smith SL, Cunningham-Sabo L. Food choice, plate waste and nutrient intake of elementary- and middle-school students participating in the US National School Lunch Program. *Public Health Nutr*. 2014;17(6):1255-1263. doi:10.1017/S1368980013001894.

38. Marlette MA, Templeton SB, Panemangalore M. Food Type, Food Preparation, and Competitive Food Purchases Impact School Lunch Plate Waste by Sixth-Grade Students. *J Am Diet Assoc*. 2005;105:1779-1782. doi:10.1016/j.jada.2005.08.033.

39. Guthrie, Joanne F; Buzby JC. Several Strategies May Lower Plate Waste in the National School Lunch Program. *FoodReview*. 2002;25(2):36-42. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.188.3768&rep=rep1&type=pdf. Accessed February 13, 2018.

40. Moreno-Black G, Stockard J. Salad bar selection patterns of elementary school children. *Appetite*. 2018;120:136-144. doi:10.1016/J.APPET.2017.08.034.

41. Adams MA, Pelletier RL, Zive MM, Sallis JF. Salad Bars and Fruit and Vegetable Consumption in Elementary Schools: A Plate Waste Study. *J Am Diet Assoc*. 2005;105(11):1789-1792. doi:10.1016/j.jada.2005.08.013.

42. Adams MA, Bruening M, Ohri-Vachaspati P. Use of Salad Bars in Schools to Increase Fruit and Vegetable Consumption: Where's the Evidence? *J Acad Nutr Diet*. 2015;115(8):1233-1236. doi:10.1016/j.jand.2015.02.010.

43. Rasmussen M, Krølner R, Klepp K-I, et al. Determinants of fruit and vegetable consumption among children and adolescents: a review of the literature. Part I: quantitative studies. *Int J Behav Nutr Phys Act*. 2006;3(1):22. doi:10.1186/1479-5868-3-22.

44. Lehto E, Ray C, Haukkala A, Yngve A, Thorsdottir I, Roos E. Predicting gender differences in liking for vegetables and preference for a variety of vegetables among 11-year-old children. *Appetite*. 2015;95:285-292. doi:10.1016/j.appet.2015.07.020.

45. Swanson M, Branscum A, Nakayima PJ. *Promoting Consumption of Fruit in Elementary School Cafeterias. The Effects of Slicing Apples and Oranges*. Vol 53.; 2009. doi:10.1016/j.appet.2009.07.015.

46. Wansink B, Just DR, Hanks AS, Smith LE. Pre-Sliced Fruit in School Cafeterias. *Am J Prev Med*. 2013;44(5):477-480. doi:10.1016/j.amepre.2013.02.003.

47. States U. *School Nutrition Dietary Assessment Study-III Summary of Findings*.; 2007. www.fns.usda.gov/cnd/. Accessed August 5, 2018.

48. Hanks AS, Just DR, Wansink B. Chocolate Milk Consequences: A Pilot Study Evaluating the Consequences of Banning Chocolate Milk in School Cafeterias. Bruce A, ed. *PLoS One*. 2014;9(4):e91022. doi:10.1371/journal.pone.0091022.

49. Livingstone MBE, Robson PJ. Measurement of dietary intake in children. *Proc Nutr Soc*. 2000;59(2):279-293. doi:10.1017/S0029665100000318.

50. Burrows TL, Martin RJ, Collins CE. A Systematic Review of the Validity of Dietary Assessment Methods in Children when Compared with the Method of Doubly Labeled Water. *J Am Diet Assoc*. 2010;110(10):1501-1510. doi:10.1016/J.JADA.2010.07.008.

51. Martin CK, Newton RL, Anton SD, et al. Measurement of children's food intake with digital photography and the effects of second servings upon food intake. *Eat Behav*. 2007;8(2):148-156. doi:10.1016/j.eatbeh.2006.03.003.

52. Martin CK, Correa JB, Han H, et al. Validity of the Remote Food Photography Method (RFPM) for Estimating Energy and Nutrient Intake in Near Real-Time. *Obesity*. 2012;20(4):891-899. doi:10.1038/oby.2011.344.

53. Hawkins K, Apolzan J, Myers C, Martin C. The Assessment of Food Intake with Digital Photography. In: *Advances in the Assessment of Dietary Intake*. Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742: CRC Press; 2017:85-111. doi:10.1201/9781315152288-6.

54. Getts KM, Quinn EL, Johnson DB, Otten JJ. Validity and Interrater Reliability of the Visual Quarter-Waste Method for Assessing Food Waste in Middle School and High School Cafeteria Settings. *J Acad Nutr Diet*. 2017;117(11):1816-1821. doi:10.1016/j.jand.2017.05.004.

55. Martin CK, Nicklas T, Gunturk B, Correa JB, Allen HR, Champagne C. Measuring food intake with digital photography. *J Hum Nutr Diet*. 2014;27(s1):72-81. doi:10.1111/jhn.12014.

56. Jia W, Chen H-C, Yue Y, et al. Accuracy of food portion size estimation from digital pictures acquired by a chest-worn camera. *Public Health Nutr*. 2014;17(8):1671-1681. doi:10.1017/S1368980013003236.

Tables and Figures

Table 4.1. Demographic descriptions of the students participating in the National School Lunch Program (NSLP) in SWITCH and control schools.

	5th grade enrollment [a]	White (%) [a]	NSLP participants [b]	FRL (%) [a]	Male [c]	Female [d]
SWITCH school 1	96	92.71	52.75 ± 3.47	5.21	43.41 ± 1.58	56.59 ± 1.58
SWITCH school 2	69	85.51	57.75 ± 2.81	15.94	43.87 ± 2.84	56.13 ± 2.84
control school 1	109	92.66	58 ± 1.68	1.83	52.89 ± 1.84	47.11 ± 1.84
control school 2	66	86.36	36.5 ± 4.5	27.27	64.26 ± 4.94	35.34 ± 4.94

[a.] Retrieved from the website of Iowa Department of Education, School Demographics 2016-2017

[b.] Represents the mean number of NSLP participants over the four data collection days for each school. Shown as mean ± Standard Error of Mean (SEM).

[c.] Represents the mean percentage of male participating NSLP over the four data collections days for each school. Shown as mean ± SEM.

[d]. Represents the mean percentage of female participating NSLP over the four data collections days for each school. Shown as mean ± SEM.

Table 4.2. Total food wasted percentages of a school lunch in SWITCH and control schools at baseline and endpoint.

	SWITCH schools (mean ± SEM)	control Schools (mean ± SEM)
Baseline	33.38 ± 2.94	35.35 ± 3.19
Endpoint	35.99 ± 2.94	26.4 ± 3.83

Table 4.3. Comparison of mean wasted percentage for each food category in SWITCH and control schools at baseline and endpoint[*]

	SWITCH schools		Control schools	
	Baseline (mean ± SEM)	Endpoint (mean ± SEM)	Baseline (mean ± SEM)	Endpoint (mean ± SEM)
Hot entrée	10.65 ± 3.02[a]	13.84 ± 3[a]	14.49 ± 3[a]	10.59 ± 3.04[a]
Cold entree	31.39 ± 7.56[a]	36.86 ± 7.47[a]	42.97 ± 6.53[a]	22.82 ± 7.61[a]
Cooked vegetable	45.07 ± 5.5[a]	44.6 ± 5.67[a]	39.74 ± 9.4[a]	16.92 ± 13.44[a]
Fresh vegetable	28.12 ± 4.79[a]	43.6 ± 4.8[b]	48.73 ± 4.16[b]	40.06 ± 4.34[b]
Fruit	48.49 ± 3.36[a]	44.24 ± 3.29[a]	40.8 ± 3.15[a]	41.61 ± 3.65[a]

[*] different letter represents significant difference, $p<0.05$

Figure 4.1. An example of paired before- and after- meal photo for a tray. Left: before the meal. Right: after the meal

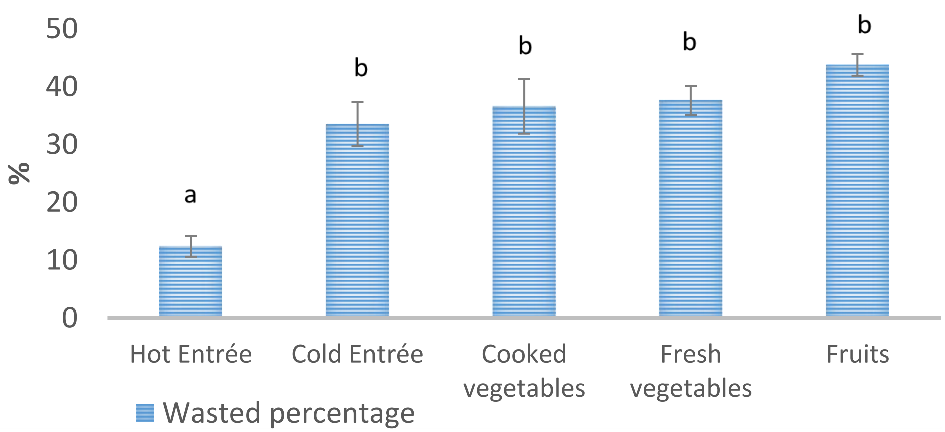


Figure 4.2. Comparison of wasted percentages among different food categories (different letter represents significant difference, $p<0.05$)

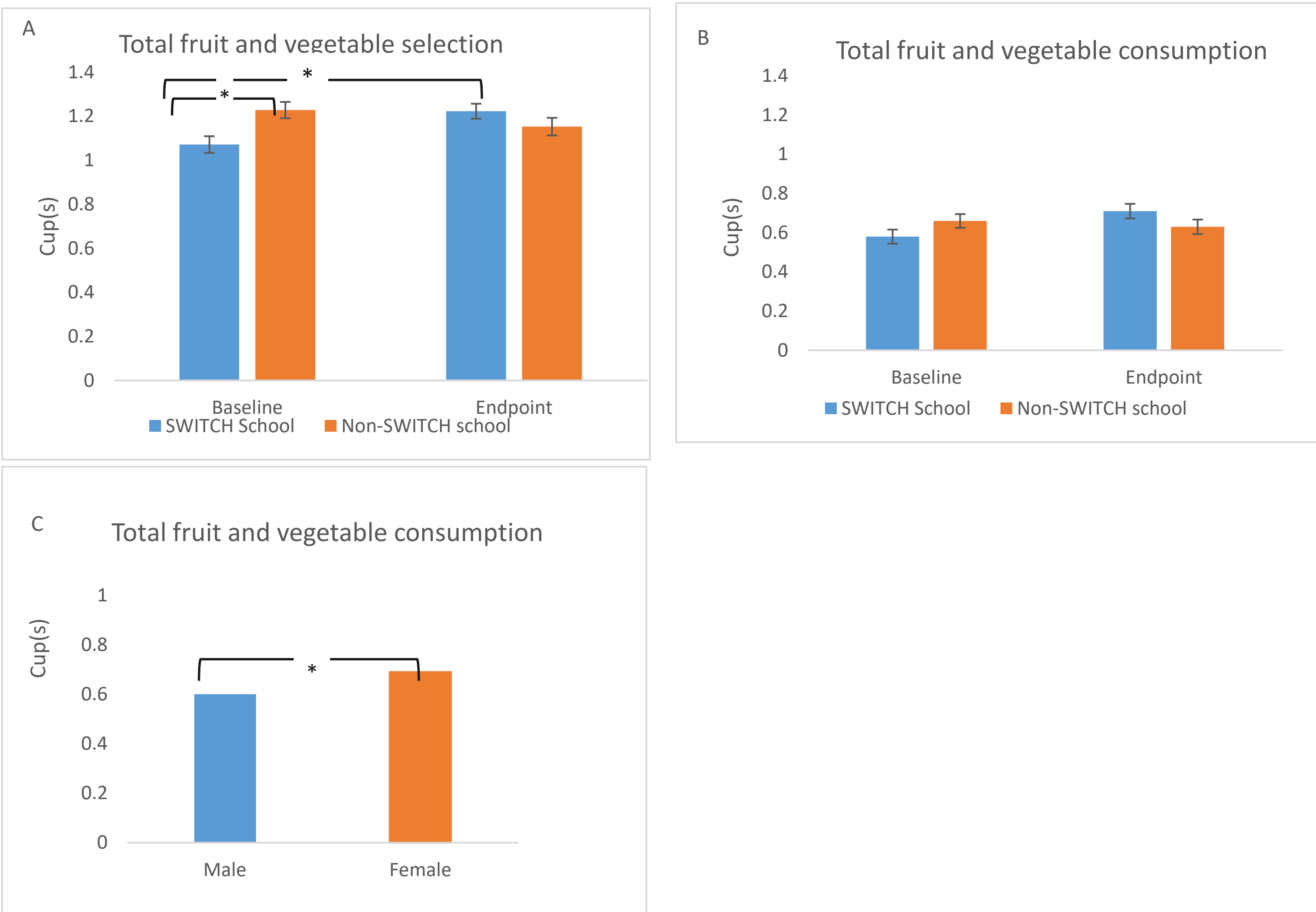


Figure 4.3. Total fruit and vegetable selection and consumption patterns (* represents significant difference, p<0.05)
A: The selection of total fruits and vegetables at baseline and endpoint in SWITCH and control schools. B: The consumption of total fruits and vegetables at baseline and endpoint in SWITCH and control schools C: Total fruit and vegetable consumption between males and females (pooled SWITCH and control schools data).

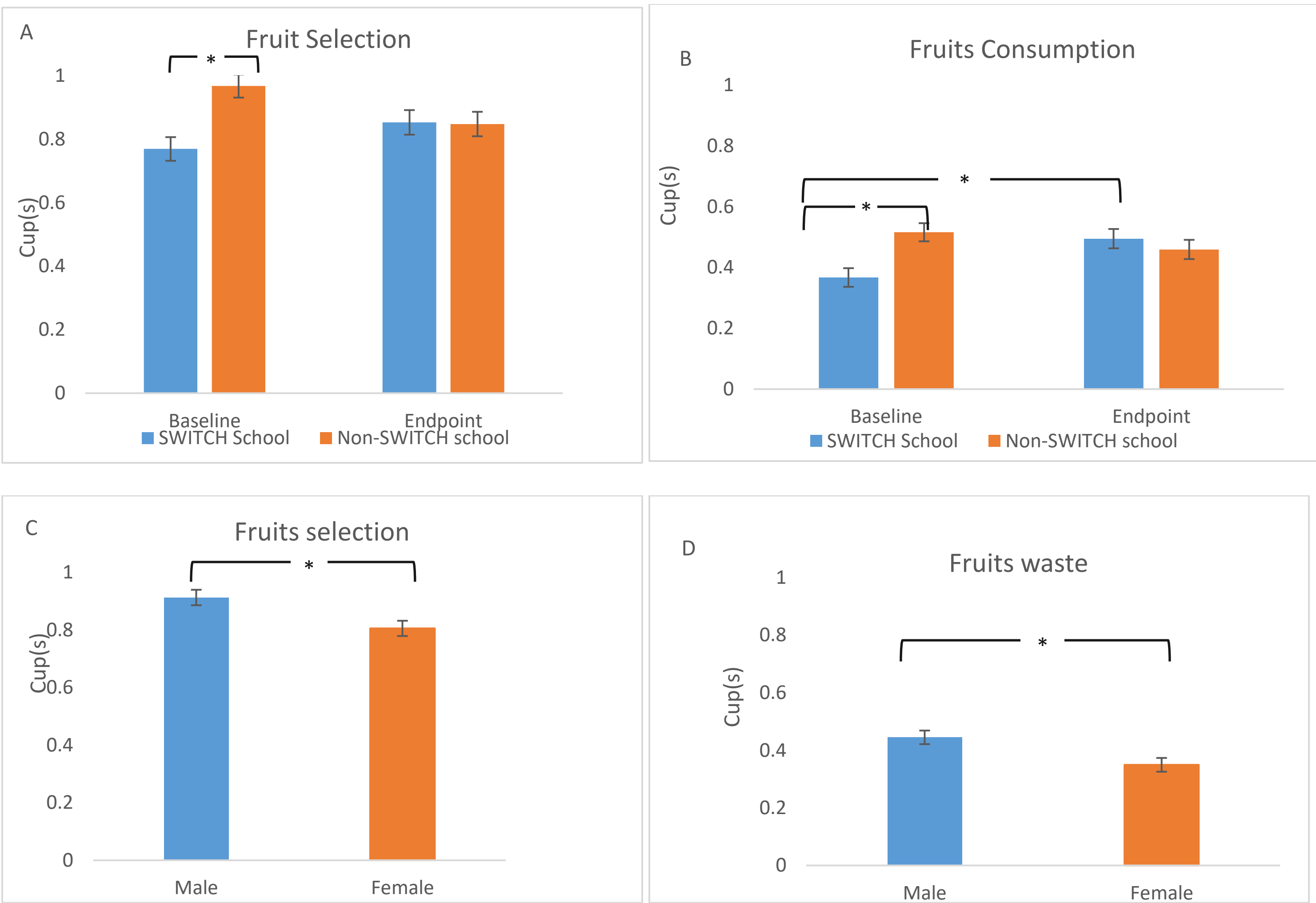


Figure 4.4. Fruit selection, consumption, and waste pattern. (* represents significant difference, $p<0.05$)
A: The selection of fruits at baseline and endpoint in SWITCH and control schools. B: The consumption of fruits at baseline and endpoint in SWITCH and control schools. C: Fruit selection between males and females (pooled SWITCH and control schools data). D: Fruit waste between males and females (pooled SWITCH and control schools data).

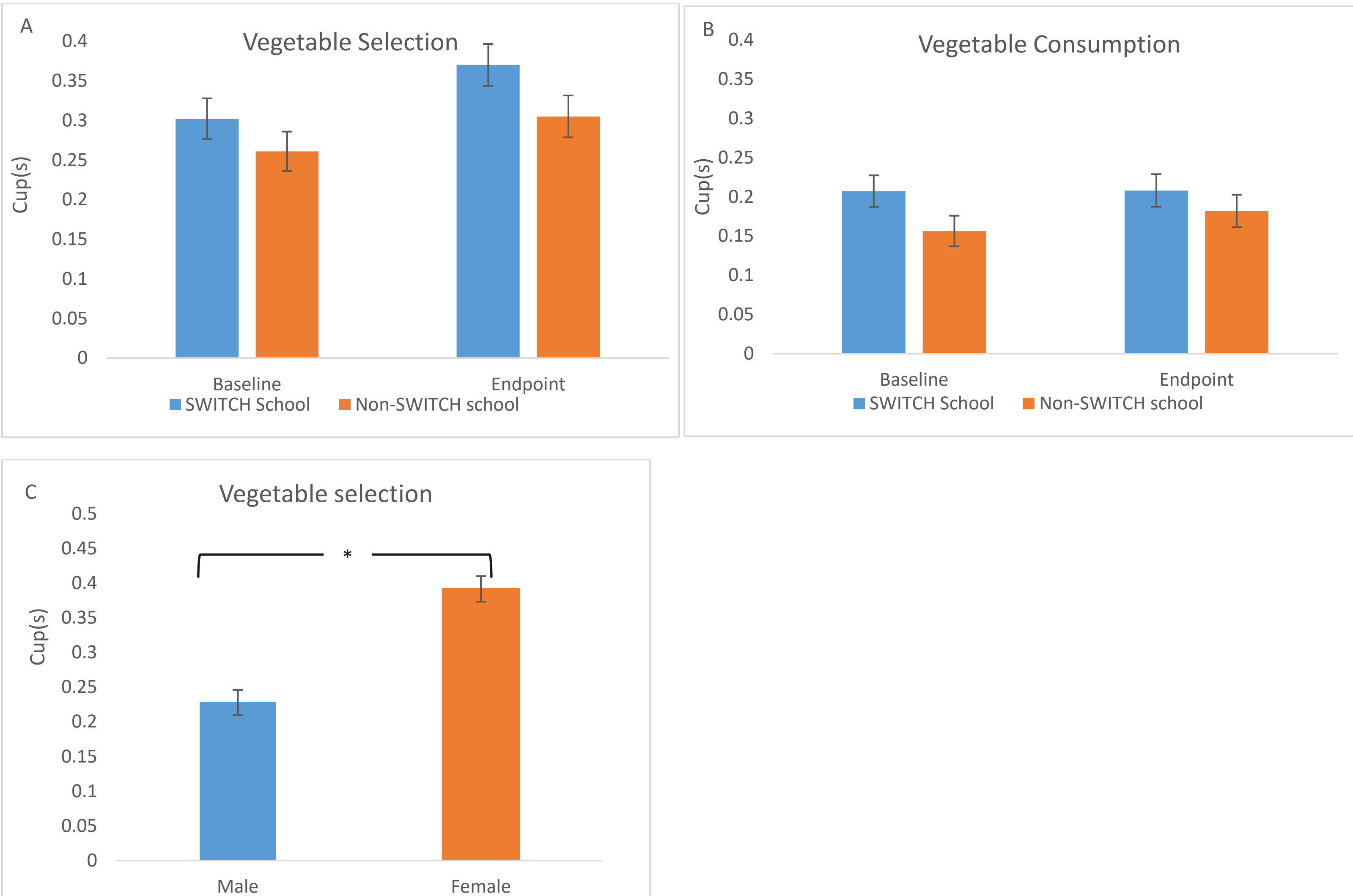


Figure 4.5. Vegetable selection, consumption, and waste pattern. (* represents significant difference, $p<0.05$)
A: The selection of vegetables at baseline and endpoint in SWITCH and control schools. B: The consumption of vegetables at baseline and endpoint in SWITCH and control schools. C: Vegetable selection between males and females (pooled SWITCH and control schools data).

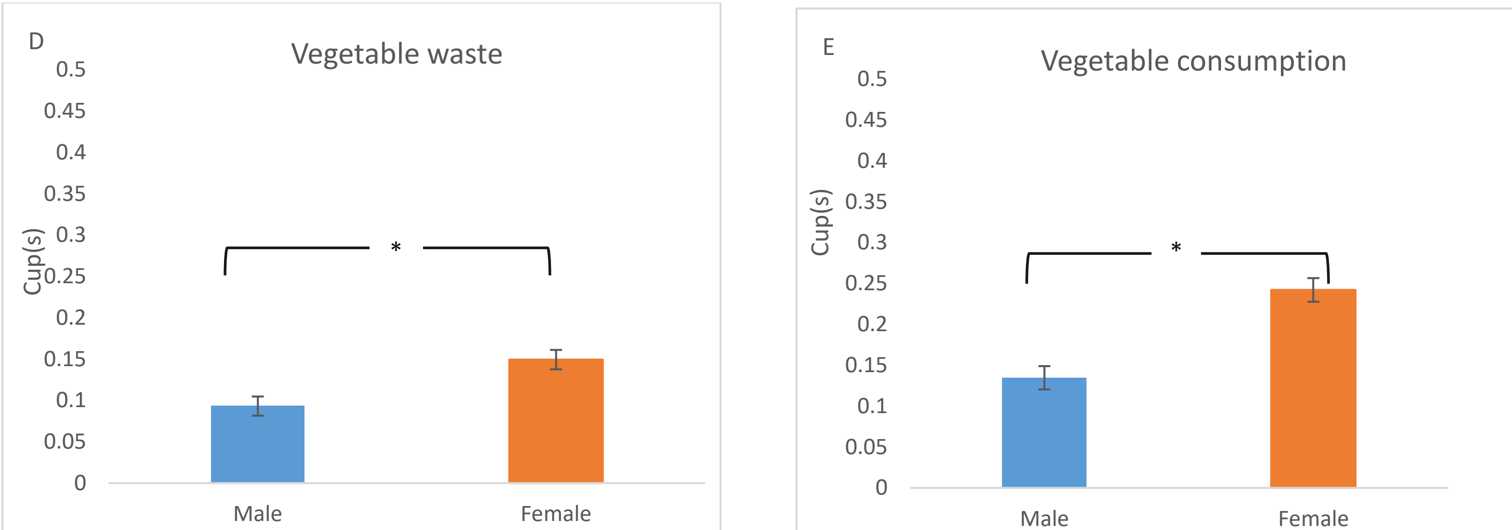


Figure 4.5.continued. Vegetable selection, consumption, and waste pattern. (* represents significant difference, $p<0.05$)
D: Vegetable waste between males and females (pooled SWITCH and control schools data). E: Vegetable consumption between males and females (pooled SWITCH and control schools data).

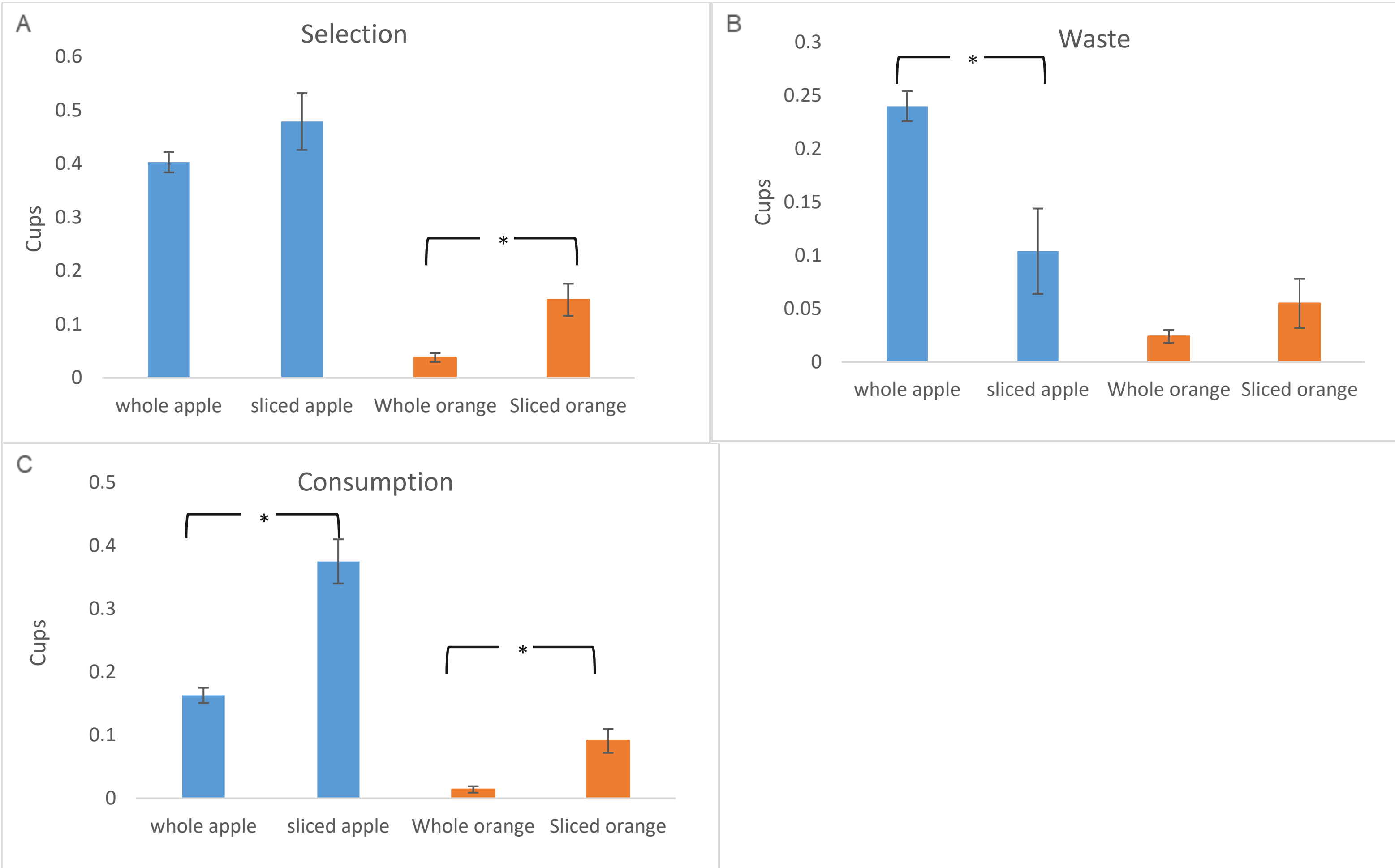


Figure 4.6. Comparison of selection, waste and consumption between whole fruits and sliced fruits (* represents significant difference, $p<0.05$)
A: Selection B: Waste C: Consumption

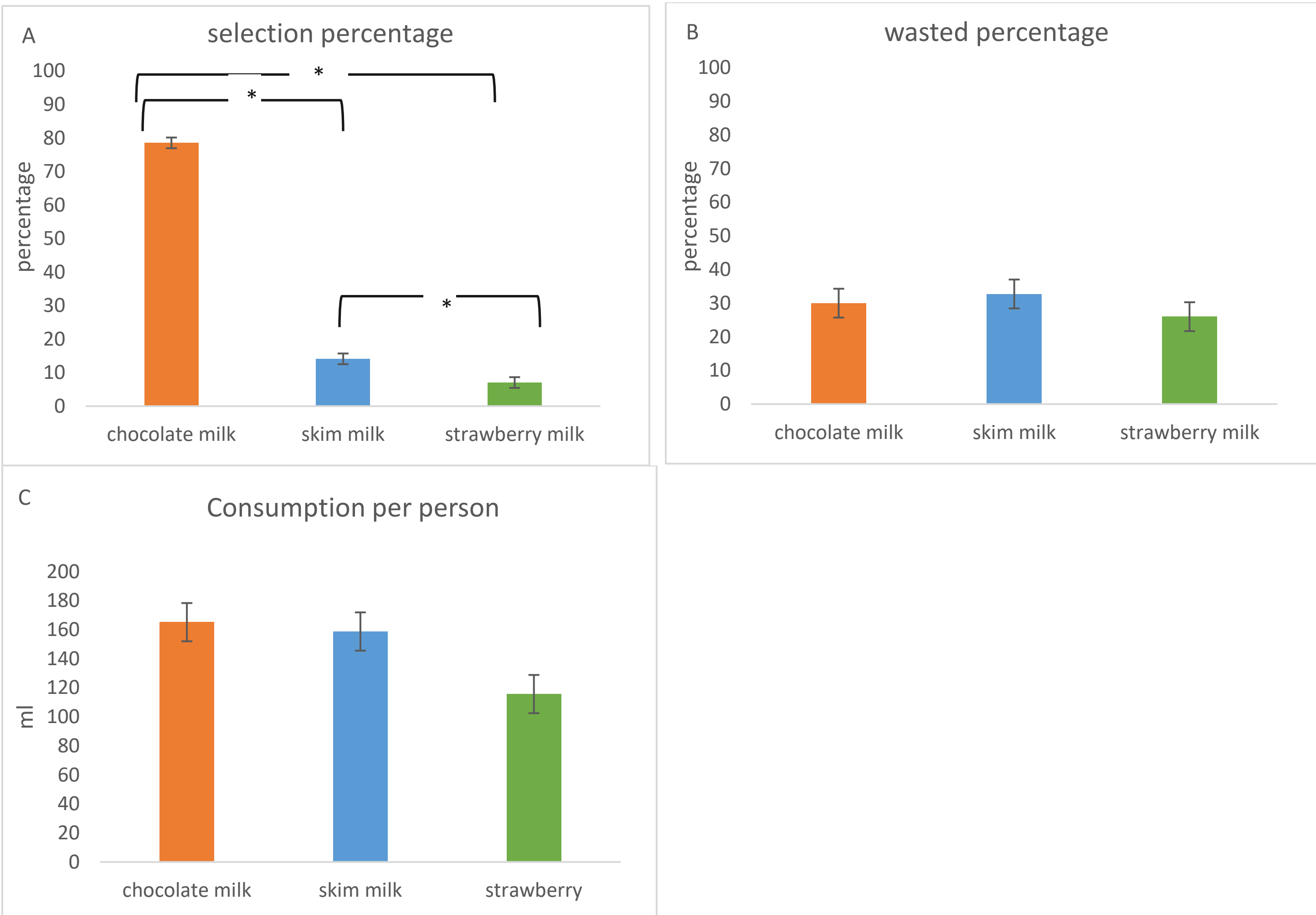


Figure 4.7.Comparison of selection, waste, and consumption among different milk types (* represents significant difference, $p<0.05$)
A: Selection percentage
B: Wasted percentage
C: Consumption per person who selected the specific type

CHAPTER 5.THE EFFECTS OF SWITCH PROGRAMMING ON ENERGY AND NUTRIENT SELECTION AND INTAKE IN SCHOOL LUNCHES

Modified from a paper to be submitted to *Journal of the Academy of Nutrition and Dietetics*

Yuanying Lou,[1] Huaiqing Wu,[2] Gregory J. Welk,[3] Spyridoula Vazou,[3] Senlin Chen,[4] Douglas A. Gentile,[5] Richard R. Rosenkranz,[6] David A. Dzewaltowski,[7] and Lorraine Lanningham-Foster[1*]

[1]Departiment of Food Science and Human Nutrition, Iowa State University, Ames, IA

[2]Departiment of Statistics, Iowa State University, Ames, IA

[1]Departiment of Kinesiology, Iowa State University, Ames, IA

[4]School of Kinesiology, Louisiana State University, Baton Rouge, LA

[5]Departiment of Psychology, Iowa State University, Ames, IA

[6]Department of Food, Nutrition, Dietetics, & Health, Kansas State University, Manhattan, KS

[7]Department of Health Promotion, Social & Behavioral Health, University of Nebraska Medical Center & Buffett Early Childhood Institute, Omaha, NE

[*]*Lorraine Lanningham-Foster will be the corresponding author (lmlf@iastate.edu)*

Abstract

Background: The school lunchroom plays a significant role in influencing students' eating behaviors. The SWITCH program empowered schools to be the pivot for improving children's healthy eating through established school modules and promoting positive environmental changes.

Objective: The purpose of the study was to examine the influence of SWITCH programming on energy and nutrient selection, intake, and percent of waste in school lunches, compared to the nutrient recommendations by National Academy of Medicine.

Study Design: Quasi-experimental design

Setting/Participants: Fifth grade students from four elementary schools within the same suburban district in mid-size Midwest community participated in this study. Among them, two schools participated in SWITCH and the other two did not. The before- and after-lunch photos were taken for a total of 740 trays over the 16 plate waste measurements.

Outcomes: Percent selection and waste were estimated for each food item on individual plates by using the Quarter system as the rating scale. The selection, intake, and wasted percentage of energy and of six nutrients including sodium, fiber, protein, carbohydrate, total fat, and saturated fat were calculated for each plate using the nutrition information of the school lunch menu items provided by the local district.

Statistical Analysis: Linear mixed models were established to detect the influence of school category, time, gender, and the interaction between school category and time on energy and nutrient selection, intake, and wasted percentage. Generalized linear mixed models were used to study the effects of these factors on whether schools meet the recommended nutrient targets.

Results: Without including the energy and nutrient content in the milk, energy and nutrient selection, as well as intake and wasted percentage between SWITCH and control schools were compared at baseline and endpoint. The results suggests SWITCH programming may significantly decreased sodium intake, increased fiber selection, and increased carbohydrate selection. When adding the energy and nutrients that were contained in milk into the selection values and comparing values to the recommended nutrient targets, the results demonstrated

SWITCH programming could improve the percentage of students who achieved the energy and fiber recommendations.

Conclusion: Implementation of the SWITCH program may help schools meet the recommended energy and fiber target, increase fiber selection, and decrease sodium selection and intake.

Key words: pediatric obesity prevention; plate waste; dietary intakes

Introduction

Since the 1980s, the obesity rate has more than doubled in children between the age of 6 to 11 years and quadrupled in adolescents between the ages of 12 to 19 years.[1] The increasing pediatric obesity prevalence has become one of the biggest challenges in the 21st century worldwide.[1,2] Children and adolescents with obesity may not only suffer from a wide range of co-morbidities, such as the increased risk for cardiovascular diseases, asthma, gastrointestinal disorders, and insulin resistance, but also experience social isolation and psychological dysfunctions.[3–5] Previous research has found that the status of being overweight for more than 6 years during childhood might increase the risk of acquiring obesity in adulthood.[7] Hence, effective treatments and interventions are in high demand to reverse the increasing prevalence of pediatric overweight and obesity.[8]

The large reach of the National School Lunch Program (NSLP) and its potential positive influence on students' dietary intakes has made the school lunchroom an important target in many childhood obesity interventions.[9–11] Previous studies provided evidence to show the modifications in school lunchroom could lead to positive influences on children's dietary intake and total health.[9–13] NSLP served 7.1 million students at the start of its creation in 1946. [14]. By 2016, it served 30.4 million students, and now has become the second largest food and nutrition assistance program across the nation. [14,18] Originally, the national school meal programs aimed to provide a safety net for children in need and reduce hunger. However, in the context of the childhood obesity epidemic in recent years, providing energy and nutrient-balanced meals to children has become a major focus in school meal programs.[16] Previous research has provided consistent evidence to show the typical diets of children and adolescents in the U.S do not meet dietary recommendations.[17] Intakes of saturated fat, total fat, and sodium exceed the upper limit of the recommendation. [18] Conversely, some nutrients such as fiber, calcium, potassium, and Vitamin E were inadequate.[18]

Before 1995, schools were only required to meet the prescribed meal patterns to qualify for federal reimbursement. *Healthy Meals for Healthy Americans Act* (P.L. 104-448) was passed by Congress in November 1994 and required schools to provide meals in NSLP and School Breakfast Program (SBP) to be consistent with the *Dietary Guidelines for American 1995.*[19] To implement this law, in 1995, *School Meals Initiative For Healthy Children* (SMI) was put into place to make the schools evaluate their compliance with appropriate nutrition standards beginning in 1996-1997.[19] Based on SMI, school lunches were to provide meals containing one third of *Recommended Dietary Allowance (RDA)* for calories, protein, vitamin A, vitamin C, calcium and iron.[20] The total fat content was set to be less than 30% of total energy, and saturated fat was no more than 10%.[20] The SMI also provided recommendations for sodium, fiber, and cholesterol, but did not set requirements for schools to meet quantitative targets. Revising and updating the meal requirements and nutrition standards was spurred by the *2004 Child Nutrition and WIC Reauthorization Act* (P.L.108-265) to promote consistency with the most recent *Dietary Guidelines for American* and *Dietary Reference Intakes* (*DRIs*). In 2010, National Academy of Medicine, formally called the Institute of Medicine (IOM), revised the *Nutrition Standards and Meal Patterns* for school meal programs and published the updated version (abbreviated as 2010 IOM recommendations in this paper).[16] As reported in previous research, the NSLP lunches provided by most schools meet the 2010 IOM recommendations.[21,22] However, the students' actual selection and consumption of school meals were out of the direct control from the meal providers under the *Offer Versus Serve* (OVS) provision. In this study, the selection of energy and nutrients per school lunch were compared to the 2010 IOM recommendations to explore which factor might provide a significant influence on the percentage of school students who could meet the nutrition standards.

The project was conducted as part of an ongoing evaluation of the SWITCH program (School Wellness Integration Targeting Child Health) which was focused on school system change.[23] As a multicomponent, socio-ecologically-based school wellness intervention program, SWITCH (School Wellness Integration Targeting Child Health) emphasizes the role of schools as a bridge to connect teachers and school wellness staff with the students, parents, and community. It aims to improve the youth behaviors through modifying factors within their surrounding physical and social environments.[6,24,25] The SWITCH program was originally designed and implemented in 2005 by the National Institute on Media and the Family, Minneapolis, MN. Starting 2012, the program was transferred to Iowa State University and a systematic modification was started to adapt the program to the current school setting. The program has been modified from the original print-based to the current web-based version, and a formative evaluation demonstrated the online version provided similar implementation results as the original.[6] The web-based programming made the communication channel more effective and provided a platform for the broader dissemination of the program. Three school modules--Classroom, Physical Education (PE), and Lunchroom--were established and became the key components during the program implementation in 2016, which engaged the classroom teachers, PE teachers, and foodservice personnel to work as a team to change the school environments and improve the children's lifestyle behaviors (i.e. "Switch what they Do, View, and Chew"). Three major goals of the SWITCH program are 1) helping children establish healthy eating behaviors, especially increasing their fruit and vegetable consumption to 5 daily servings, 2) increasing their moderate physical activity to at least 60 minutes each day, and 3) decreasing recreational screen time to 2 hours or less each day.

Previous research has shown multicomponent school-based interventions is an effective way to increase fruit and vegetable consumption in youth.[13] Among the modules implemented in the SWITCH program, the Classroom module and the PE module both provide materials to enhance education on basic nutrition/health concepts, such as energy balance, MyPlate food groups, and food label information. The Lunchroom module provides strategies and resources to help school modify their cafeteria environment and improve the quality of the school meals. Schools are also supported to provide fruit and vegetable tastings to encourage students to try new fruits and vegetables in order to increase their consumption.

In the SWITCH evaluation, specific emphasis was placed on developing methods to evaluate school level changes in selection and consumption of food at lunch. Self-reported measurements, including 24-hour diet recall, food frequency questionnaire, and diet history, were widely used in previous research.[26–28] However, validity and accuracy of these methods were criticized, especially for children with overweight and obesity.[29,30] Another common method used in school plate waste studies was the weighing method, which is also called "gold standard" due to its high accuracy and reliability.[31] But its applications were limited because it was time-consuming and labor-intensive.[32–34] Recently, the photo-based visual estimation method has become more widely used considering it is easy to implement, highly flexible, and cost-effective.[35–37] In a previous study (Chapter 3), we compared four systems (Third/Quarter/Eighth/Continuous) used in the visual estimations. The results indicated the Quarter system might be a good choice in visual estimations due to its high accuracy and high preference. Therefore, in this study, the Quarter system was adopted for quantifying the food and nutrient waste, selection, and intake.

The results in Chapter 4 of this dissertation demonstrated the positive influence brought by the SWITCH program on increasing fruit consumption. Whether the increased fruit intake could contribute to the improvements in nutrient intake was not explored. The primary objective of this study was to investigate the influence of SWITCH programming on the selection, intake and wasted percentage of energy and of six nutrients including sodium, fiber, protein, carbohydrate, total fat, and saturated fat. It was hypothesized that SWITCH programming could provide a positive influence on improving nutrient intake.

Methods

Study Design and Participants

The SWITCH initiative is an ongoing project aimed at promoting school system change to enhance school wellness programming. The feasibility of the SWITCH implementation process was previously described by Chen et al. (2018),[38] and SWITCH implementation during 2017 was introduced in Chapter 4.

In 2017, the SWITCH program was implemented in eight elementary schools across the state of Iowa. A quasi-experimental design was used to evaluate food related outcomes associated with SWITCH programming. To accomplish this, two schools enrolled in SWITCH were matched with two non-participating schools from the same district. While not randomized into the two conditions, the matching through the same suburban school district provides a robust design since food policy and lunch programs were standardized across the district. Because the SWITCH program was only implemented in 5th grade in the two SWITCH schools, the plate waste measurements were only conducted in students participating in NSLP in 5th grade of the participating schools.

Study Ethics

The research was conducted as part of the overall SWITCH evaluation plan, which was reviewed by Iowa State University *Institutional Review Board* (IRB). The file of IRB approval (IRB # 14-651) is attached in Appendix G. In approval of the study, the IRB determined that written informed consent could be waived as all program information collected was de-identified before sharing with the researchers. All food and nutrients data collected in this study was de-identified.

Measurements and Data Collection

The design for plate waste measurements was the same as in the previous study (Chapter 4). Briefly, a total of 16 plate waste measurements were conducted in four schools before and after the implementation of the SWITCH program. Before the program implementation started (i.e. baseline), two separate days were chosen for each school to collect the plate waste data from students; after the program implementation finished (i.e. endpoint), another two separate days were chosen for each school to collect the data again.

Different menu items may influence food selection and consumption, which may result in changes in energy and nutrient intake. Therefore, all plate waste measurement days were chosen purposely to reduce this confounding effect. The menu items were kept consistent on measurement days between SWITCH and control schools, and were also comparable between baseline and endpoint. The table in Appendix H lists all menu items on each measurement day.

Study Procedure

Collecting food waste photos

The photo-based food visual estimation method has been developed and widely used in school-based dietary measurements in previous research [34,35,37,39–41]. In our study, this method was adopted as an objective measurement to estimate food selection and consumption for each student. The protocol of collecting food waste photos was described in detail in Chapter 4. Figure 5.1 shows an example of a pair of before- and after-lunch photos for the same lunch tray.

Estimating food selection, waste, and consumption

All photos were downloaded to the computers in the research lab, and before-lunch photos were paired with the after-lunch photo for the same. Gender was identified based on the camera used to take before-lunch photos. When conducting the visual estimations, a paired before- and after-lunch photo along with the reference photos for fruits and vegetables (with MyPlate reference serving sizes) were shown on the computer screen simultaneously. The Quarter system was chosen to be used as the rating scale in the visual estimation in this study. Comparing the after-lunch photo with the before-lunch photo, the percent food waste was estimated for each food item using the following points: all wasted, ¾ wasted, ½ wasted, ¼ wasted, and none wasted. Likewise, selection percentage for fruit or vegetable was estimated by comparing the before-photo with the responding reference photo. Using the following formulas, the selection, waste, and consumption amount could be calculated:

*Selection amount (cups equiv.) = selection percentage *reference volume*

*Waste amount (cups equiv.) = wasted percentage * selection volume*

Consumption amount (cups equiv.) = selection volume -waste volume

For the food with standard initial portion size and served by the food service personnel (e.g. hot entrée), the selection amount was the standard serving size. Only the last two formulas were needed to calculate waste and consumption amount for this type of food.

The food wasted percentages were estimated by two research assistants simultaneously. A third person served as the tiebreaker if the two could not reach an agreement. To make sure the research assistant could estimate accurately and with high reliability, a four to six-hour long, systematic training was provided. The validity and interrater reliability were tested. Their Root Mean Square Error (RMSE) was calculated to be less than 0.15 when compared the estimation value with the true weight of the tested food items, indicating high accuracy. The intraclass correlation demonstrated the agreement between the two research assistants was high (r=0.92).

Defining nutrient selection, intake, and wasted percentage

The food service program in the local school district provided the nutrition information for individual menu items on each measurement day, including information about energy (kcal), sodium (mg), fiber (g), protein (g), carbohydrate (g), saturated fat (%), and total fat (%). In this study, we used the term "energy/nutrient selection" to indicate the amount of energy/nutrient from a specific food or a school lunch selected by individual students. Similarly, energy/nutrient intake is the amount of energy/nutrient from a specific food or a school lunch consumed by individual students. Energy/nutrient waste was calculated by subtracting the energy/nutrient intake from the energy/nutrient selection. The wasted percentage of energy/nutrient is the ratio of energy/nutrient waste to energy/nutrient selection.

The selection of energy and the six nutrients were calculated for each menu item using the following formula:

*Energy/Nutrient (one specific) selection for one specific food item = selected percentage of reference value for that food * Energy/Nutrient value (one specific) in the food item*

It should be noted that the reference value in the formula above was the standard serving size provided on the menu nutrition information from schools. They may or may not have been the same as the MyPlate standard serving sizes, which were used as the reference sizes in estimating food selection amount. If the sizes of the two references were not the same, first we had to convert the selected percentage based on the reference value provided by schools.

By combining the energy or nutrient selection from all food items on a plate except for milk, the total energy or nutrient selection was calculated for each student (i.e. plate). Similarly, the energy/nutrient intake was calculated using the formula above, just by replacing the selected percentage with the consumed percentage.

To calculate the energy percentage from total fat or saturated fat, the first step was to calculate the total fat or saturated fat selection (g) and intake (g). Then calculations followed the equation:

$$\text{Total/ Saturated fat selection or intake \%} = \frac{\text{Total/Saturated fat selection or intake } (g) * 9 \text{ kcal/g}}{\text{total energy selection or intake (kcal)}}$$

Unlike the other food items, only the total wasted volume from the whole 5th grade was collected for milk on each measurement day. Therefore, milk waste and consumption could not be specified at the individual level, but could only be estimated at the school level. However, the milk carton selected by each student was captured in the before-photos. Three types of milk were provided in the lunchrooms of this school district: skim milk, strawberry milk, and chocolate milk. According to the specific type of milk chosen by each individual, the energy and nutrient content in that milk was determined. The total energy or nutrient selection for individual plates (including the selected milk) could be calculated by adding the values of other food items.

Statistical Modules

Statistical Analysis Software 9.4 (SAS Institute, Cary, NC) was performed for the data analysis. Two series of analysis were conducted to investigate the patterns of energy and nutrient selection, intake and wasted percentage.

Comparing energy and nutrient selection, intake, and wasted percentage between SWITCH and control schools

Because the milk consumption could not be estimated at the individual level, the energy and nutrients contained in the milk were not added to the total values.

A total of 21 mixed models were established to explore the influence of different factors on selection, intake, and wasted percentage of energy and each nutrient. In each mixed model, the selection/intake/wasted percentage of food energy or of each nutrient was the response outcome, the school category (SWITCH schools vs. control schools), time (baseline vs. endpoint), gender (male vs. female), and the interaction between school category and time were treated as the fixed effects. The difference between individuals and between schools in each category were treated as the random effects.

Least square means for different levels of one predicting variable were calculated, and pairwise comparisons were conducted with Tukey adjustment. Adjusted p values were reported for each pair of comparison and statistical significance was set as $p \leq 0.05$.

Comparing the nutrient selection in SWITCH and control schools to the recommended nutrient targets by the IOM

Only the selection of food energy and the six nutrients examined in this study were compared with the 2010 IOM recommendations. Since the milk selection could be identified at the individual level, the energy and nutrient content in the milk were included in the total selection value only.

When comparing the energy and each nutrient selection value with the responding recommendation by the IOM, 1 was recorded if it met the recommendation and 0 was recoded if it did not. Seven generalized linear mixed models were established to test whether meeting the recommendation for energy or one specific nutrient was influenced by various factors, including school category, time, gender, and the interaction between school category and time. Random effects of differences between individuals and between schools in each category were used to justify the models.

Multiple pairwise comparisons were performed with the Tukey adjustment used, and adjusted p values were reported. Comparisons would be considered significant at the 0.05 level. The results were presented as the percentage of students who could meet the IOM recommendation. Least square means for each nutrient and energy were calculated in SWITCH and control schools, and the data was shown as mean with the standard error of the mean (SEM).

Results

Descriptive Characteristics of Study Participants

Since the four schools participating in this study were the same as in Chapter 4, the descriptive characteristics of the schools are shown in Table 4.1. Only 5th grade students in each school were included, and an average enrollment number in this grade per school was 85. To make the study results more comparable between SWITCH and control schools, two control schools were matched with the two SWITCH schools based on their demographic characteristics. Control school 1 corresponded to SWITCH school 1 with a larger enrolment number and lower free-reduced lunch (FRL) rate. Control school 2 was chosen to match SWITCH school 2 with a lower enrollment number and higher FRL rate. The average daily NSLP participation number of 5th grade across the four schools was 46.3, and there was no significant difference between the two school categories. A total of 740 individual trays were photographed during the 16 plate waste measurements.

Comparing Energy and Nutrient Selection, Intake, and Wasted Percentage between SWITCH and Control Schools—Not Including the Energy and Nutrient Content in Milk

The energy (kcal), sodium (mg), fiber (g), protein (g), carbohydrate (g), total fat (%), and saturated fat (%) selected and consumed from a school lunch (not including the nutrient content in milk) were compared between SWITCH and control schools. For energy and each nutrient, the values of food selection, intake, and wasted percentage per school lunch were calculated for each 5th grade student, based on the visual estimations and the nutrient information provided by the school. Table 5.1 shows the least square mean of energy and each nutrient averaged across the multiple measurement days at baseline and endpoint.in that specific school category.

Energy

Although the increase of energy intake from baseline to endpoint was not statistically significant when compared in SWITCH or control schools separately (p=0.47 and 0.25, respectively), the average energy intake of the four schools at endpoint was significantly higher than that at baseline (Figure 5.2 A, least square mean = 358 and 336 kcal, respectively, SEM = 18 kcal, p=0.02). Time may influence the energy wasted percentage, indicated by the p vale approaching significance (Figure 5.2 B, p=0.069).

Sodium

Average sodium selection of the four schools decreased from baseline to endpoint (Figure 3 A, least square mean = 639 and 611 mg, respectively, SEM = 54 mg, p=0.03). This decrease may be related to a significant decrease of sodium selection in SWITCH schools (Figure 3 B, p=0.04), because the decrease in control schools was not statistically significant (Figure 3 B, p=0.979). Gender had a significant influence on sodium selection: males selected much less sodium than females (Figure 5.3 C, p=0.008). In SWITCH schools, sodium intake decreased from 596 mg to 565 mg from baseline to endpoint, while in control schools, it increased from 427 mg to 461 mg (Figure 5.3 D).The average sodium wasted percentage across the four schools decreased from 19% at baseline to 15% at endpoint (Figure 5.3 E, p=0.04).

Fiber

There was a significant increase on fiber selection from 6.7 g at baseline to 7.5 g at endpoint in SWITCH schools compared to control schools (Figure 5.4 A, p=0.04). Averaging across the four schools, fiber intake at endpoint was significantly higher than baseline (Figure 5.4 B, least square mean = 4.8 and 4.4 g, respectively, SEM = 0.2 g, p=0.04). In SWITCH schools, fiber wasted percentage slightly increased from baseline to endpoint, while in control schools, it decreased (Figure 5.4 C, p=0.11 and 0.58, respectively).

Carbohydrate

Carbohydrate selection increased in SWITCH schools but decreased in control schools (Figure 5.5 A, p= 0.27 and 0.7, respectively). The average carbohydrate intake of the four schools increased from 45.1 g at baseline to 47.7 g at endpoint (Figure 5.5 B, p=0.05).

Comparing the Nutrient Selection in SWITCH and Control Schools to the Recommended Nutrient Targets Set by the IOM –Including the Nutrient Content in Milk

Table 5.2 summarizes the least square means of the selection of each nutrient in each school category at baseline and endpoint, including the nutrients contained in milk. The nutrient recommendations by the IOM were used as the standards, and the percentage of students who met the specific nutrient recommendations was calculated and is also presented in Table 5.2.

Energy

The recommended energy range offered to students in a school lunch is from 550 kcal to 650 kcal.[16] The average total energy selection in both SWITCH and control schools at baseline or endpoint fell within this recommended range (550-650 kcal). However, less than half of the students met the energy target range. Shown in Figure 5.6, at baseline, the percentage of students meeting the energy recommendation in control schools was significantly higher than SWITCH schools (42± 3.5 % and 29 ± 3.4 %, respectively, p=0.04). From baseline to endpoint, there was a significant increase of the percentage from 29% to 47% in SWITCH schools (p=0.002), but a slight decrease in control schools from 42% to 35% (p=0.59). Among the students who did not meet the IOM energy recommendation, we found the majority had the energy selection less than 550 kcal per school lunch (Appendix K).

Sodium

The schools were still using 1230 mg as the upper limit when planning for their lunch during data collection in 2017. The average sodium selection per school lunch in both SWITCH and control schools at baseline or endpoint was below 1000 mg. The percentage of students who met the sodium recommendation in SWITCH schools was significantly lower than control schools both at baseline and endpoint (Figure 5.7, p<0.001 for both).

Fiber

The average fiber selection failed to meet the IOM recommendation (8.5 g) in SWITCH schools or control schools, at both baseline and endpoint. Across all the measurement days, the percentage of students meeting the fiber recommendation in SWITCH schools was significantly higher than in control schools (Figure 5.8 A, p <0.001). From baseline to endpoint, the percentage increased from 27% to 38% in SWITCH schools, however, the percentage decreased slightly in control schools from 19% to 17% (Figure 5.8 B, p=0.06 and 0.98, respectively). At endpoint, the percentage in SWITCH schools was significantly higher than in control schools (p<0.001).

Protein

The average protein selection in both school categories at baseline or endpoint was above 25 g, much higher than the IOM recommended target (15.2 g). The percentage of students meeting the protein recommendation in SWITCH schools was significantly higher than control schools averaging over all measurement days (p =0.03).

Total fat

The average percentage of energy from total fat calculated in SWITCH and control schools at baseline and endpoint fell into the IOM recommended range (25%-35%). However, when further analyzing the percentage of students who met the total fat recommendation, only about half of students in SWITCH schools and a third of students in control schools met this recommendation (Table 5.2). The percentage of students who met the recommendations in SWITCH schools was significantly higher than control school both at baseline and endpoint (p = 0.041 and 0.001, respectively).

In SWITCH schools, at baseline, the percentage of students who had a total fat selection greater than 35% was higher than the percentage of students had a total fat selection less than 25%, but at the endpoint, the two percentages were almost the same (Appendix K). However, in control schools, no matter at baseline or endpoint, almost half of students who had a total fat selection less than 25% (Appendix K).

Saturated fat

The average percentage of energy from saturated fat was 9% and 8% in SWITCH and control schools, respectively, which met the saturated fat recommendation (less than 10%). The percentage meeting the recommendation in SWITCH schools was significantly lower than that in control schools (p =0.01).

Discussion

SWITCH is an ongoing project focusing on promoting school system change to help students cultivate healthy lifestyle behaviors, including healthy eating, regular physical activity, and reduced screen time. Our previous results showed that SWITCH programming may positively influence fruit consumption by increasing the fruit selection (Chapter 4). Testing whether the increases in fruit selection and consumption could influence intake of food energy and nutrients is important for evaluating the effects of SWITCH programming. Hence, the first objective of this study was to assess the impacts of the SWITCH program on students' energy and nutrient selection, intake, and waste through school lunch. The photo-based food visual estimation method using the Quarter system as the rating scale was selected to measure the students' dietary intake during school lunches. In addition to food energy, six nutrients were analyzed in this study including sodium, fiber, protein, carbohydrate, total fat, and saturated fat. The information for these nutrients contained in a school lunch was provided by the food service program in the local school district.

Previous research has shown that most schools participating in NSLP could provide school lunches meeting the nutrition standards.[22] However, in the context of the OVS provision which allows students to decline some food items provided in a reimbursable school meal, the actual selection and consumption could be less than the recommendations. Therefore, it is very important and necessary to determine what students select and consume, not simply knowing what the school offers. Through comparing the selection of energy and specific nutrients in foods by each student to the nutrient targets recommended by the IOM, the percentage of students who met the recommendation for each nutrient and energy was calculated. The influence from different factors including school category, time, and gender was investigated.

In the context of the increasing prevalence of childhood obesity in recent years, providing a school lunch with appropriate energy content has become essential. In the updated IOM nutrient targets published in 2010, the upper limit for energy offered and selected in a school meal was added.[16] IOM recommended the energy per school lunch should fall into the range of 550-650 kcal. Some studies have demonstrated that the energy amount in a school lunch was very likely to exceed the upper limit.[15,42,43] Martin and colleague (2010) showed that the average energy selection in a school lunch for 5th grade students was 776 kcal.[15] Whereas in two other studies, the energy selection was estimated to be much lower, around 658 kcal and 676 kcal per school lunch, respectively.[42,43] In our study, the average energy selection per school lunch was calculated to be 566 kcal (SEM=3 kcal), falling into the IOM recommended range for energy and was closer to the lower end of the range. Martin *et al*. (2010) found only 14.4% of students met the energy recommendation, and the majority of those who did not meet the energy recommendation were above the upper limit, selecting over 650 kcal in a school lunch.[15] Interestingly, our data suggests 38.5% of students could meet the IOM energy target range, and the majority of those who did not meet the energy recommendation were below the lower end, selecting under 550 kcal in a school lunch. One possible explanation for the lower energy selection in our study is that the energy contained in condiments (e.g. salad dressing and sauce) was not included in the total energy selection. Since some condiments were not separate and usually spread over the other food items, it was hard to accurately estimate the amount of condiments selected by students. According to the nutrition information of the menu items, the energy content in a typical serving of condiment is about 70-100 kcal. Adding the energy content in condiments to the total energy selection, the value now can be up to around 650 kcal, which is at the upper end of the recommended energy range. Some other possible reasons for the discrepancies of the results could be the different study populations and school locations, different menu items, and different study designs and dietary assessment methods quantifying the intake of food and nutrients.

Although SWITCH programming did not significantly influence average energy selection, it significantly increased the percentage of students who met the IOM energy range from 29% at baseline to 47% at endpoint in SWITCH schools, in contrast to the decrease from 42% to 35% that occurred in control schools (Figure 5.6). Analyzing average selection, intake, and waste of energy per school lunch, our results indicated the factor of time, not SWITCH programming may have a significant influence. Regardless of energy selection, intake or waste, there was no significant difference in any comparisons between SWITCH and control schools at baseline and endpoint. However, if combining the two school categories together, the decrease in waste resulted in a significant increase in energy intake from baseline to endpoint (Figure 5.2 A).

According to The Third School Nutrition Dietary Assessment Study (SNDA-III study), sodium intake for all schoolchildren is clearly excessive.[44] It was estimated that more than 90% of the schoolchildren had their usual sodium intake exceeding the Tolerable Upper Limit (UL) for sodium based on their age.[44] Decreasing sodium content has become an emphasis in school meals, and the upper limit for sodium was added in the 2010 IOM recommendations. Based on the recommendation, the sodium provided in a school lunch should be less than 640 mg. A phased approach to sodium reduction with three steps have been proposed with the final recommendation of < 630 mg being implemented in the school year 2022-2023. During our data collection in 2017, schools still used the upper limit of 1230 mg. Crepinsek *et al.* (2009) estimated the sodium selection per school lunch to be 1278 mg.[43] In our study, the average sodium selection of the four schools across all measurement days was 796 mg, which was lower than the upper limit of 1230 mg. Again, the sodium content in condiments was not included in total sodium selection. About 300 mg sodium was contained in a typical serving of condiment, which increased the average sodium selection per school lunch in our study to be around 1100 mg. Both at baseline and endpoint, the percentage of students meeting the IOM sodium recommendation in control schools was significantly higher than that in SWITCH schools. However, this difference between SWITCH and control schools might be mostly related to the school differences, and not directly related to SWITCH programming. Although at endpoint, the percentage of students meeting the sodium recommendation in SWITCH schools was still lower than control schools, the implementation of SWITCH did bring a positive influence on sodium intake by significantly decreasing the sodium selection (Figure 5.3 B and D). The decreased sodium selection in SWITCH schools might be related to the increased fruit selection (Chapter 4), since there was less sodium contained in fruit compared to other types of food provided in a school meal.

Another benefit, which may also have resulted from the increased fruit selection, was the increased fiber selection in SWITCH schools. After SWITCH implementation, the fiber selection significantly increased in SWITCH schools, while it decreased in control schools (Figure 5.4 A). In addition, SWITCH programming could positively influence the percentage of students who met the IOM fiber recommendation. At endpoint, 38% of the students participating in NSLP in SWITCH schools met the IOM fiber target, significantly higher than 17% in control schools (Figure 5.8 B). However, compared to the IOM standard, which recommends schools to provide at least 8.5 g fiber per school lunch, none of the four schools at baseline or endpoint met this target. SNDA-III data showed the low fiber intake has become a challenge for all schoolchildren in different age groups and it was the least consumed nutrients in the NSLP lunches.[44] Our results showed 32% of the fiber in foods selected by students would be wasted during the lunch (SEM = 1%). The average fiber selection in our study was 6.8 g per school lunch, which was very similar to the results shown previously in two studies with fiber intake of 6 g and 7 g, respectively.[42,43]. Smith and colleague (2014) found only 8% of students could meet the IOM fiber requirement.[45]. However, in our study, the mean percentage of students meeting the recommendation was 25%.

Excessive fat intake, in particular the saturated fat, has become a big concern for its negative influence on children's health.[16] According to the 2008 Diet Quality Report, almost 80% of all children in different age groups exceeded the recommended daily saturated fat intake.[46] It was also the biggest challenge for school food service programs to provide meals meeting the SMI standards for total fat and saturated fat. In the school year 2004-2005, more than 70% of the NSLP lunches offered by schools met the SMI standards for most of the key target nutrients except for total fat and saturated fat.[44] Since then, schools participating in the NSLP have made significant progress in meeting the target for total fat and saturated fat. As shown in the SNDA-IV study, in the school year 2009-2010, almost three quarters of all schools offered or served the average NSLP lunch meeting the 2010 IOM recommendation for total fat, and more than three quarters of all schools met the recommendation for saturated fat.[21] The IOM recommended the energy from total fat should fall into the range from 25% to 35%, and the energy from saturated fat should be less than 10%. As shown in SNDA-IV study and some previous research, meeting the recommendation for total fat could be achieved by most schools, however, it was harder to meet the recommendation for saturated fat. [15,21,42,45,47,48] In our study, the mean percentage of energy from total fat was estimated to be 28% (SEM = 0.3%), falling into the recommended range. Moreover, an average of 41% of the students in the four schools across all measurement days met the IOM total fat recommendation. Our results showed the mean percentage of energy from saturated fat was 8.7% (SEM = 0.2%), and an average of 65% of students in the four schools had the saturated fat intake less than 10%. For those who could not meet the IOM recommended target range for total fat, previous research indicated the majority had the energy from total fat greater than 35%.[15,43] However, in the control schools participating in our study, at baseline and endpoint, the majority of those who did not meet the recommended range had the energy from fat less than 25%. In SWITCH schools, students were more likely to have the total fat selection be above the upper end at baseline. However, at endpoint, the percentage of students with total fat selection above the upper end was almost the same as the percentage with the total fat selection below the lower end (Appendix K). This indicated that SWITCH programming might influence those students whose total fat selection did not meet the IOM recommendation.

The report of SNDA-IV study showed more than 97% of schools offered and served NSLP lunches that could meet and exceed the IOM recommendation for protein, which is 15.2 g per school lunch.[21] Similarly, the mean selection of protein in our study was 25.6 g per school lunch, and almost 100% of students could meet the protein target. Although there was a significant difference between SWITCH and control schools in the percentage of students meeting the protein recommendation (Figure 5.9, 100% in SWITCH schools, 99% in control schools, p=0.03), this difference was mainly related to the existing difference among different school categories before SWITCH was introduced.

The influence of SWITCH on carbohydrate selection was significant (p =0.04). SWITCH programming may contribute to the increased carbohydrate selection, especially when comparing to the decrease that occurred in control schools (Figure 5.5A). The increased fruit selection in

SWITCH schools may be related to the increase in carbohydrate selection, considering the carbohydrate content in fruits.

This study was built on the ongoing research on the SWITCH model evaluating school system change. In previous work we demonstrated the implementation of the SWITCH program could have a positive influence on fruit consumption (Chapter 4). In this study, school level changes were evaluated using mixed model, and the results suggests the SWITCH programming may also be beneficial to help students improve their energy and nutrient selection and intake. However, there were still some limitations in this study. First, the nutrient targets recommended by IOM were applied to an average NSLP lunch over a five-day week. However, we measured the students' dietary intakes on two separate days in each school both at baseline and at endpoint. Therefore, the different menu items in the chosen days might have some influence on energy and nutrient intake. Nevertheless, we chose the measurement days based on the cycle menu shared in the district to keep the menu items on different days comparable and consistent (See details in Method). Second, all four schools participating in the study were from a suburban school district in Iowa. The less diverse socio-economic background may limit the generalization of the study results. Thirdly, energy and nutrient selections were compared to the 2010 IOM recommendations in the study. However, the original purpose for the nutrient recommendations set by the IOM is to help schools for menu planning by setting scientific standards. In other words, the standards were set for schools to provide meals meeting/nearly meeting the recommendations, not for students for their selections or intakes. Nevertheless, comparing the percentage of students whose nutrient selections whether meet specific recommendations between SWITCH and control schools still provided us information about the influence of SWITCH programming on students' dietary intakes. A final limitation is that it was not possible to fully evaluate the degree to which program implementation could influence the results. As a dissemination study, SWITCH is focused on evaluating implementation under real-world conditions. Therefore, it is not possible to directly manage the fidelity of implementation. The main studies utilize more of an implementation framework to study the outcomes associated with high and low levels of implementation but this was not possible with the small sample of schools involved in these studies. Subsequent work with these models will enable the school lunch outcomes to be evaluated within this implementation framework

Conclusions

The data in this study provide evidence to show that the implementation of the SWITCH program could have some positive influence on helping students meet the IOM energy and fiber recommendation for school lunch, increase fiber selection, and decrease sodium selection and intake.

Acknowledgements

This work was supported in part by the United States Department of Agriculture National Institute of Food and Agriculture (NIFA) grant 2014-08390 "Dissemination of the evidence-based SWITCH program for childhood obesity prevention." This work is solely the responsibility of the authors and does not necessarily represent the views of the USDA.

Authors' Contributions

YL and LLF was responsible for the study design. GJW, SV, SC, DAG, RRR, DAD, and LLF contributed to the development and implementing the SWITCH program. YL and LLF conducted the plate waste studies and collected the data. YL processed the photos and led the visual estimations. YL and HW analyzed the data. YL drafted the first manuscript with the contributions from LLF. All authors reviewed and commented on subsequent drafts of the manuscript.

Author Disclosure Statement

No competing financial interests exist.

References

1. Fryar CD, Carroll MD, Ogden CL. Prevalence of Overweight and Obesity Among Children and Adolescents: United States, 1963–1965 Through 2011–2012. *Natl Heal Nutr Exam Surv*. 2012. https://www.cdc.gov/nchs/data/hestat/obesity_child_11_12/obesity_child_11_12.pdf. Accessed March 20, 2018.

2. UNICEF, WHO, World Bank Group. *LEVELS AND TRENDS IN CHILD MALNUTRITION 156 MILLION*.; 2016. http://www.who.int/nutgrowthdb/jme_brochure2016.pdf. Accessed March 20, 2018.

3. Must A, Strauss R. Risks and consequences of childhood and adolescent obesity. *Int J Obes*. 1999;23(S2):S2-S11. doi:10.1038/sj.ijo.0800852.

4. Deckelbaum RJ, Williams CL. Childhood Obesity: The Health Issue. *Obes Res*. 2001;9(S11):239S-243S. doi:10.1038/oby.2001.125.

5. Gortmaker SL, Must A, Perrin JM, Sobol AM, Dietz WH. Social and Economic Consequences of Overweight in Adolescence and Young Adulthood. *N Engl J Med*. 1993;329(14):1008-1012. doi:10.1056/NEJM199309303291406.

6. Welk GJ, Chen S, Nam YH, Weber TE. A formative evaluation of the SWITCH® obesity prevention program: print versus online programming. *BMC Obes*. 2015;2(1):20. doi:10.1186/s40608-015-0049-1.

7. Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH. Predicting Obesity in Young Adulthood from Childhood and Parental Obesity. *N Engl J Med*. 1997;337(13):869-873. doi:10.1056/NEJM199709253371301.

8. Koplan JP, Liverman CT, Kraak VI, Committee on Prevention of Obesity in Children and Youth. Preventing childhood obesity: health in the balance: executive summary. *J Am Diet Assoc*. 2005;105(1):131-138. doi:10.1016/j.jada.2004.11.023.

9. Williamson DA, Han H, Johnson WD, Martin CK, Newton RL. Modification of the school cafeteria environment can impact childhood nutrition. Results from the Wise Mind and LA Health studies. *Appetite*. 2013;61:77-84. doi:10.1016/j.appet.2012.11.002.

10. Williamson DA, Champagne CM, Harsha DW, et al. Effect of an Environmental School-Based Obesity Prevention Program on Changes in Body Fat and Body Weight: A Randomized Trial. *Obesity*. 2012;20(8):1653-1661. doi:10.1038/oby.2012.60.

11. Williamson DA, Copeland AL, Anton SD, et al. Wise Mind Project: A School-based Environmental Approach for Preventing Weight Gain in Children*. *Obesity*. 2007;15(4):906-917. doi:10.1038/oby.2007.597.

12. Williamson DA, Champagne CM, Harsha D, et al. Louisiana (LA) Health: Design and methods for a childhood obesity prevention program in rural schools. *Contemp Clin Trials*. 2008;29(5):783-795. doi:10.1016/j.cct.2008.03.004.

13. Blanchette L, Brug J. Determinants of fruit and vegetable consumption among 6-12-year-old children and effective interventions to increase consumption. *J Hum Nutr Diet*. 2005;18(6):431-443. doi:10.1111/j.1365-277X.2005.00648.x.

14. States Department of Agriculture U. *THE NATIONAL SCHOOL LUNCH PROGRAM*. http://www.fns.usda.gov/tn/team-nutrition. Accessed August 3, 2018.

15. Martin CK, Thomson JL, LeBlanc MM, et al. Children in School Cafeterias Select Foods Containing More Saturated Fat and Energy than the Institute of Medicine Recommendations1–4. *J Nutr*. 2010;140(9):1653-1660. doi:10.3945/jn.109.119131.

16. Stallings VA, Suitor CW, Taylor CL. *School Meals*.; 2010. doi:10.17226/12751.

17. Gleason P, Suitor C. Children's Diets in the Mid-1990s: Dietary Intake and Its Relationship with School Meal Participation. *Math Policy Res Reports*. https://ideas.repec.org/p/mpr/mprres/8db693ba4d8640ec87d978a342a6ec5d.html. Accessed August 8, 2018.

18. Medicine I of. *Food Marketing to Children and Youth*. Washington, D.C.: National Academies Press; 2006. doi:10.17226/11514.

19. Gordon AR, Cohen R, Crepinsek MK, Fox MK, Hall J, Zeidman E. The Third School Nutrition Dietary Assessment Study: Background and Study Design. *J Am Diet Assoc*. 2009;109(2):S20-S30. doi:10.1016/j.jada.2008.10.057.

20. Martin D. *NF97-315 Overview of the USDA School Meals Initiative for Healthy Children Part of the Agriculture Commons, and the Curriculum and Instruction Commons*.; 1997. http://digitalcommons.unl.edu/extensionhisthttp://digitalcommons.unl.edu/extensionhist/421. Accessed August 8, 2018.

21. Fox MK, Condon E. *School Nutrition Dietary Assessment Study-IV Summary of Findings*.; 2012. www.fns.usda.gov/cnd. Accessed August 5, 2018.

22. Miller CH. A Practice Perspective on the Third School Nutrition Dietary Assessment Study. *J Am Diet Assoc*. 2009;109(2):S14-S17. doi:10.1016/j.jada.2008.11.006.

23. Krebs NF, Jacobson MS, American Academy of Pediatrics Committee on Nutrition. Prevention of pediatric overweight and obesity. *Pediatrics*. 2003;112(2):424-430. doi:10.1542/PEDS.112.2.424.

24. Eisenmann JC, Gentile DA, Welk GJ, et al. SWITCH: rationale, design, and implementation of a community, school, and family-based intervention to modify behaviors related to childhood obesity. *BMC Public Health*. 2008;8(1):223. doi:10.1186/1471-2458-8-223.

25. Gentile DA, Welk G, Eisenmann JC, et al. Evaluation of a multiple ecological level child obesity prevention program: Switch®what you Do, View, and Chew. *BMC Med*. 2009;7(1):49. doi:10.1186/1741-7015-7-49.

26. Bingham SA, Gill C, Welch A, et al. Comparison of dietary assessment methods in nutritional epidemiology: weighed records v. 24 h recalls, food-frequency questionnaires and estimated-diet records. *Br J Nutr*. 1994;72(4):619. doi:10.1079/BJN19940064.

27. Howat PM, Mohan R, Champagne C, Monlezun C, Wozniak P, Bray GA. Validity and reliability of reported dietary intake data. *J Am Diet Assoc*. 1994;94(2):169-173. doi:10.1016/0002-8223(94)90242-9.

28. Hock K, Tallman D, Kaur D, Mat Daud Z, Khosla P, Karupaiah T. Dietary assessment methods. *J Ren Nutr Metab*. 2018;3(1):8. doi:10.4103/2395-1540.232539.

29. Boushey CJ, Spoden M, Zhu FM, Delp EJ, Kerr DA. Conference on "New technology in nutrition research and practice" Symposium 1: New technologies in dietary assessment New mobile methods for dietary assessment: review of image-assisted and image-based dietary assessment methods. 2016. doi:10.1017/S0029665116002913.

30. Collins CE, Watson J, Burrows T. Measuring dietary intake in children and adolescents in the context of overweight and obesity. *Int J Obes*. 2010;34(7):1103-1115. doi:10.1038/ijo.2009.241.

31. Hanks AS, Wansink B, Just DR. Reliability and accuracy of real-time visualization techniques for measuring school cafeteria tray waste: validating the quarter-waste method. *J Acad Nutr Diet*. 2014;114(3):470-474. doi:10.1016/j.jand.2013.08.013.

32. Comstock EM, St Pierre RG, Mackiernan YD. Measuring individual plate waste in school lunches. Visual estimation and children's ratings vs. actual weighing of plate waste. *J Am Diet Assoc*. 1981;79(3):290-296. http://www.ncbi.nlm.nih.gov/pubmed/7264115. Accessed January 15, 2018.

33. Kirks BA, Wolff HK. A comparison of methods for plate waste determinations. *J Am Diet Assoc*. 1985;85(3):328-331. http://www.ncbi.nlm.nih.gov/pubmed/3973322. Accessed January 19, 2018.

34. Williamson DA, Allen HR, Martin PD, Alfonso AJ, Gerald B, Hunt A. Comparison of digital photography to weighed and visual estimation of portion sizes. *J Am Diet Assoc*. 2003;103(9):1139-1145. doi:10.1016/S0002-8223(03)00974-X.

35. Swanson M. Digital Photography as a Tool to Measure School Cafeteria Consumption. *J Sch Health*. 2008;78(8):432-437. doi:10.1111/j.1746-1561.2008.00326.x.

36. Taylor JC, Yon BA, Johnson RK. Reliability and Validity of Digital Imaging as a Measure of Schoolchildren’s Fruit and Vegetable Consumption. *J Acad Nutr Diet*. 2014;114(9):1359-1366. doi:10.1016/j.jand.2014.02.029.

37. Stumbo PJ. New technology in dietary assessment: a review of digital methods in improving food record accuracy. 2018. doi:10.1017/S0029665112002911.

38. Chen S, Dzewaltowski DA, Rosenkranz RR, et al. Feasibility study of the SWITCH implementation process for enhancing school wellness. doi:10.1186/s12889-018-6024-2.

39. Williamson DA, Allen HR, Martin PD, Alfonso A, Gerald B, Hunt A. Digital photography: A new method for estimating food intake in cafeteria settings. *Eat Weight Disord - Stud Anorexia, Bulim Obes*. 2004;9(1):24-28. doi:10.1007/BF03325041.

40. Martin CK, Newton RL, Anton SD, et al. Measurement of children’s food intake with digital photography and the effects of second servings upon food intake. *Eat Behav*. 2007;8(2):148-156. doi:10.1016/j.eatbeh.2006.03.003.

41. Taylor JC, Sutter C, Ontai LL, Nishina A, Zidenberg-Cherr S. Feasibility and reliability of digital imaging for estimating food selection and consumption from students’ packed lunches. *Appetite*. 2018;120:196-204. doi:10.1016/j.appet.2017.08.037.

42. Templeton SB, Marlette MA, Panemangalore M. Competitive Foods Increase the Intake of Energy and Decrease the Intake of Certain Nutrients by Adolescents Consuming School Lunch. *J Am Diet Assoc*. 2005;105:215-220. doi:10.1016/j.jada.2004.11.027.

43. Crepinsek MK, Gordon AR, McKinney PM, Condon EM, Wilson A. Meals Offered and Served in US Public Schools: Do They Meet Nutrient Standards? *J Am Diet Assoc*. 2009;109(2):S31-S43. doi:10.1016/J.JADA.2008.10.061.

44. States U. *School Nutrition Dietary Assessment Study-III Summary of Findings*.; 2007. www.fns.usda.gov/cnd/. Accessed August 5, 2018.

45. Smith SL, Cunningham-Sabo L. Food choice, plate waste and nutrient intake of elementary- and middle-school students participating in the US National School Lunch Program. *Public Health Nutr*. 2014;17(6):1255-1263. doi:10.1017/S1368980013001894
.

46. *Nutrition Assistance Program Report Series Office of Research, Nutrition and Analysis Special Nutrition Programs*.; 2008. http://www.fns.usda.gov/oane. Accessed August 5, 2018.

47. Gleason PM, Suitor CW. Eating at School: How the National School Lunch Program Affects Children's Diets. *Am J Agric Econ*. 2003;85(4):1047-1061. doi:10.1111/1467-8276.00507.

48. Mathias KC, Jacquier E, Eldridge AL. Missing Lunch Is Associated with Lower Intakes of Micronutrients from Foods and Beverages among Children and Adolescents in the United States. *J Acad Nutr Diet*. 2016;116:667-676. doi:10.1016/j.jand.2015.12.021.

Tables and Figures

Table 5.1. The nutrient selection, intake, and wasted percentage[1] per school lunch in SWITCH and control schools (not including the energy and nutrients in milk[2])

	Energy [3] (kcal)			Sodium [3] (mg)			Fiber[3] (g)			Protein[3] (g)			Carbohydrate[3] (g)			Total fat [3] (%)			Saturated fat [3] (%)		
	Select -ion	Intake	waste %	Select -ion	Intake	waste %	Select -ion	Intake	waste %	Select -ion	Intake	waste %	Select -ion	Intake	waste %	Select -ion [4]	Intake [4]	waste %	Select -ion[4]	Intake [4]	waste %
SWITCH - baseline	437 ±26	339 ±25	22 ±1.7	732 ±77	596 ±60	18 ±1.7	6.7± 0.4	4.5± 0.3	32 ±4.2	18± 0.2	14.8 ±0.4	18 ±1.8	60.9 ±4.1	43.5 ±4.5	26 ±2.5	29± 2	31± 2	16 ±1.7	9±3	9±3	14± 2
SWITCH - endpoint	448 ±26	357 ±25	20 ±1.7	684 ±77	565 ±60	16 ±1.7	7.5± 0.4	5.1± 0.3	39 ±4.2	17.7 ±0.2	14.8 ±0.4	16 ±1.8	64.1 ±4.2	47.6 ±4.5	25 ±2.6	28± 2	31± 2	16 ±1.7	9±3	9±3	14± 1.8
control - baseline	441 ±26	336 ±25	23 ±1.7	546 ±77	427 ±60	20 ±1.6	6.4± 0.4	4.3± 0.3	31 ±4.2	17.8 ±0.2	14.2 ±0.4	20 ±1.8	64.2 ±4.1	46.7 ±4.5	27 ±2.5	27± 2	27± 2	20 ±1.6	8±3	8±3	19± 1.9
control - endpoint	437 ±26	358 ±25	18 ±1.8	539 ±77	460 ±60	13 ±1.8	6.2± 0.4	4.5± 0.3	28 ±4.3	17.9 ±0.3	15.4 ±0.4	14 ±1.8	62.3 ±4.2	47.7 ±4.6	22 ±2.6	28± 2	29± 2	14 ±1.8	8±3	8±3	14± 1.8

Note: 1. Wasted percentage was calculated by the equation: wasted % = $\frac{nutrient\ selection - nutrient\ intake}{nutrient\ selection}$

2. All the data in this table did not included the nutrient content in milk.

3. Each value shown as least square mean ± standard error of the mean (SEM)

4. Total/ Saturated fat selection or intake % = $\frac{Total/Saturated\ fat\ selection\ or\ intake\ (g) * 9\ kcal/g}{total\ energy\ selection\ or\ intake\ (kcal)}$

Table 5.2. The recommended nutrient targets for the NSLP and nutrient selection per school lunch in SWITCH and control schools (including the energy and nutrients in milk[1])

	Recommended Nutrients targets for NSLP [2]	SWITCH schools --baseline		SWITCH schools --endpoint		Control schools --baseline		Control schools --endpoint	
		Selection [4]	Meeting target(%) [5]	Selection [4]	Meeting target(%) [5]	Selection [4]	Meeting target(%) [5]	Selection [4]	Meeting target(%) [5]
Energy (kcal)	550-650	566±7	29±3.5	576±7	47±3.7	562±7	42±3.4	560±7	35±3.7
Sodium (mg)	1230 (630) [3]	922±20	87±1.6	870±16	91±1.7	702±8	100±1.6	696±8	100±1.7
Fiber (g)	8.5	6.8±0.2	27±3.1	7.6±0.2	38±3.2	6.4±0.2	19±3	6.3±0.2	17±3.2
Protein (g)	15.2	26.1±0.3	100±0.6	25.7±0.3	100±0.6	25.4±0.3	99±0.6	25.4±0.3	99±0.6
Total fat (%)	25-35	30±0.6	48±3.6	29±0.6	51±3.7	27±0.6	35±3.4	28±0.7	31±3.7
Saturated fat (%)	<10	9±0.3	59±3.5	9±0.3	63±3.6	8±0.3	71±3.4	9±0.3	68±3.6

Note: 1. All the data in this table include the nutrient content in the milk.
2. The targets for various nutrients are recommended for the NSLP as the standards for menu planning.
3. The target for sodium now used is 1230 mg, 630 mg target will be in effect in the school year of 2022-2023.
4. Shown as Least square mean ± SEM
5. Represents the percentage that meet the recommended target for that specific nutrient, shown as Least square mean ± SEM

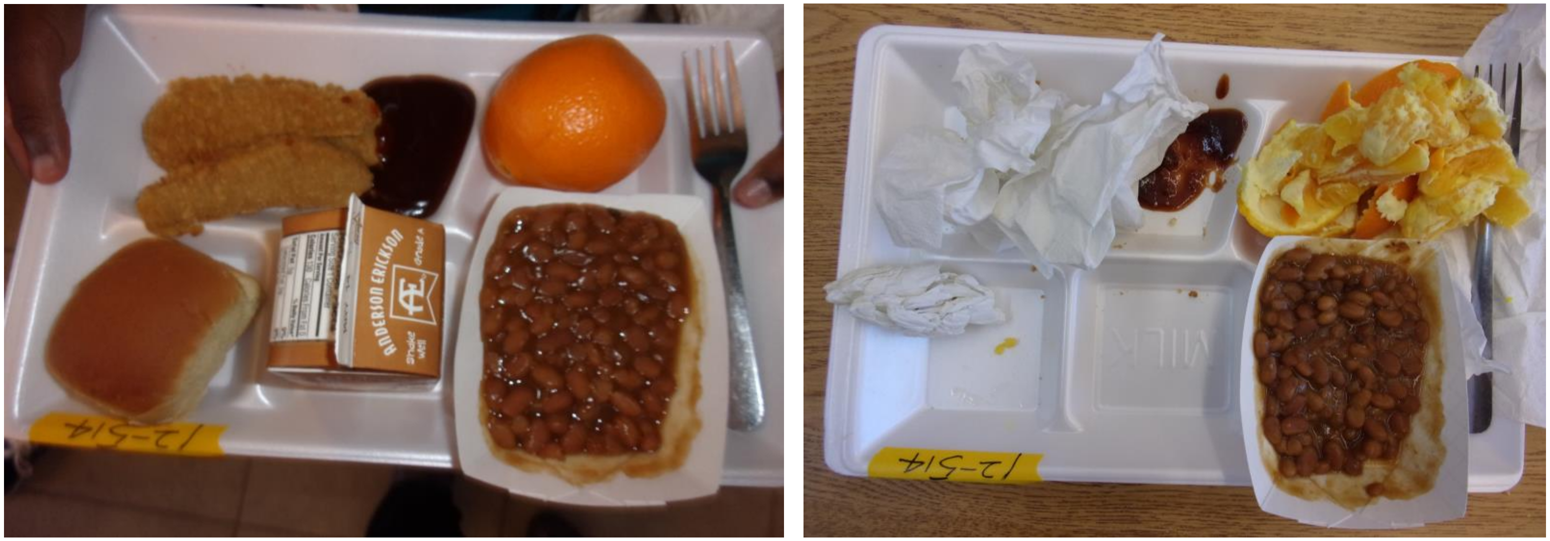


Figure 5.1. An example of paired before- and after- meal photo for a tray. Left: before the meal   Right: after the meal

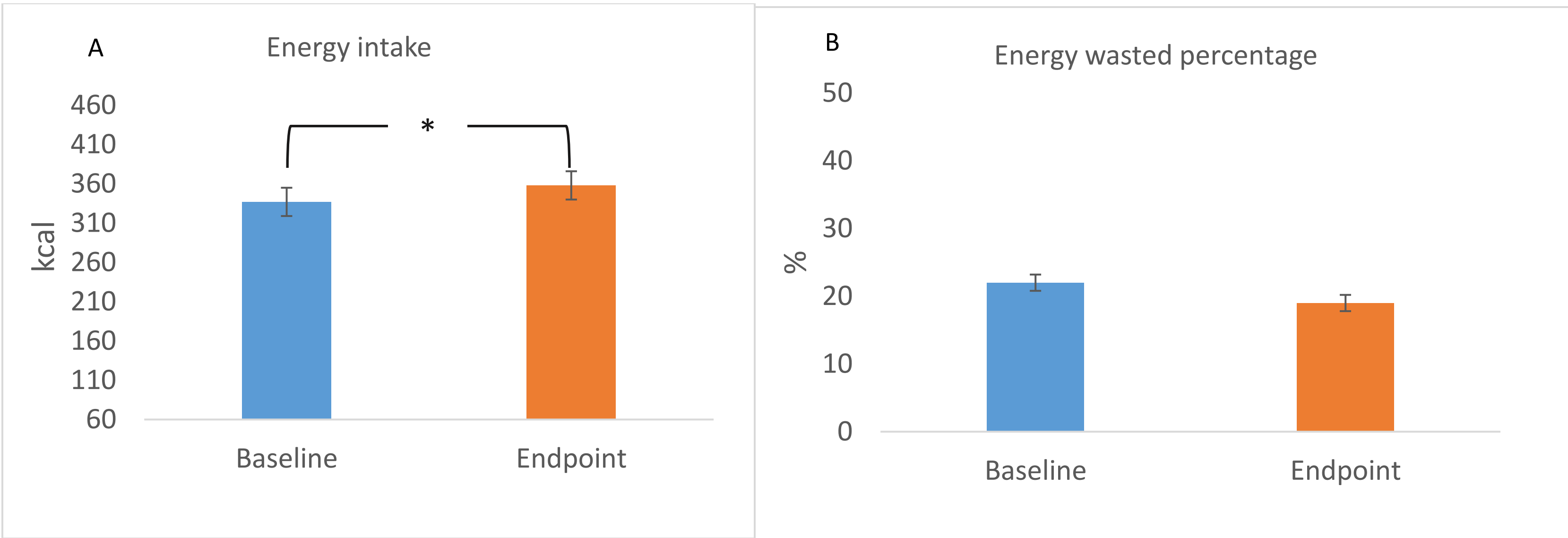


Figure 5.2. Energy intake and wasted percentage.
A: Energy intake, * represents significant difference, $p<0.05$. B: Energy wasted percentage, $p=0.07$

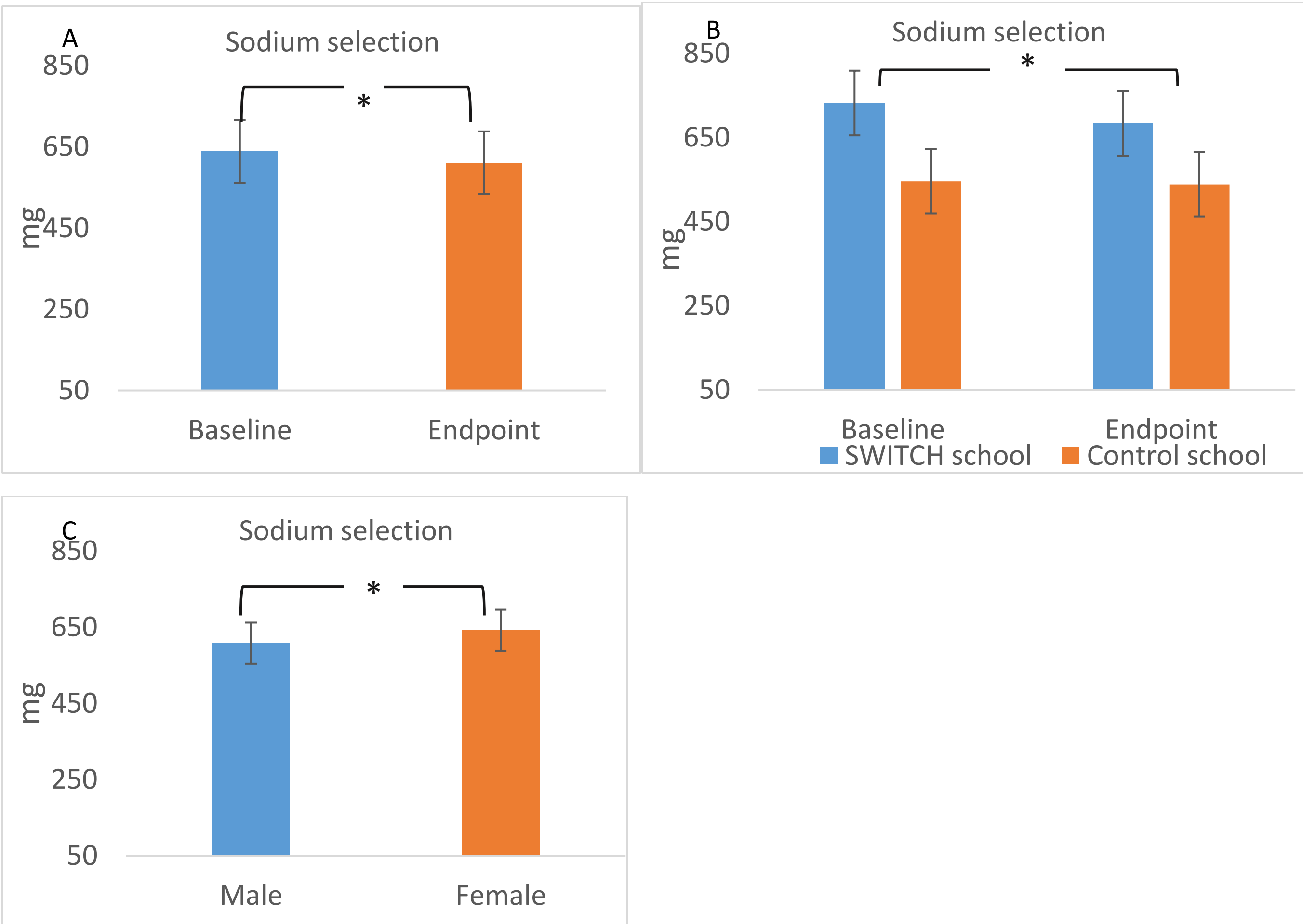


Figure 5.3. Sodium selection, intake and wasted percentage. (* represents significant difference, $p<0.05$)
A: Sodium selection comparing between baseline and endpoint (averaged across SWITCH and control schools).
B: Sodium selection comparing between SWITCH and control schools at baseline and endpoint.
C: Sodium selection comparing between males and females (averaged across all schools in all measurement days).

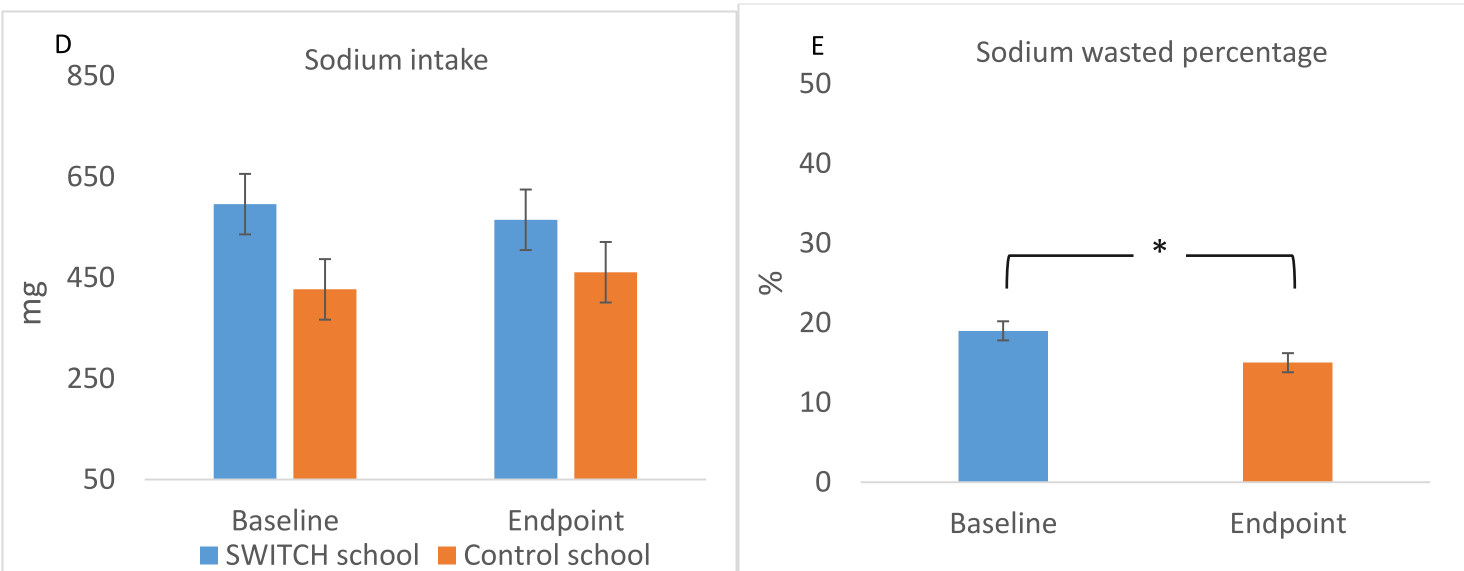


Figure 5.3. Continued. Sodium selection, intake and wasted percentage. (* represents significant difference, $p<0.05$)
D: Sodium intake comparing between SWITCH and control schools at baseline and endpoint.
E: Wasted percentage of sodium comparing between baseline and endpoint (averaged across SWITCH and control schools).

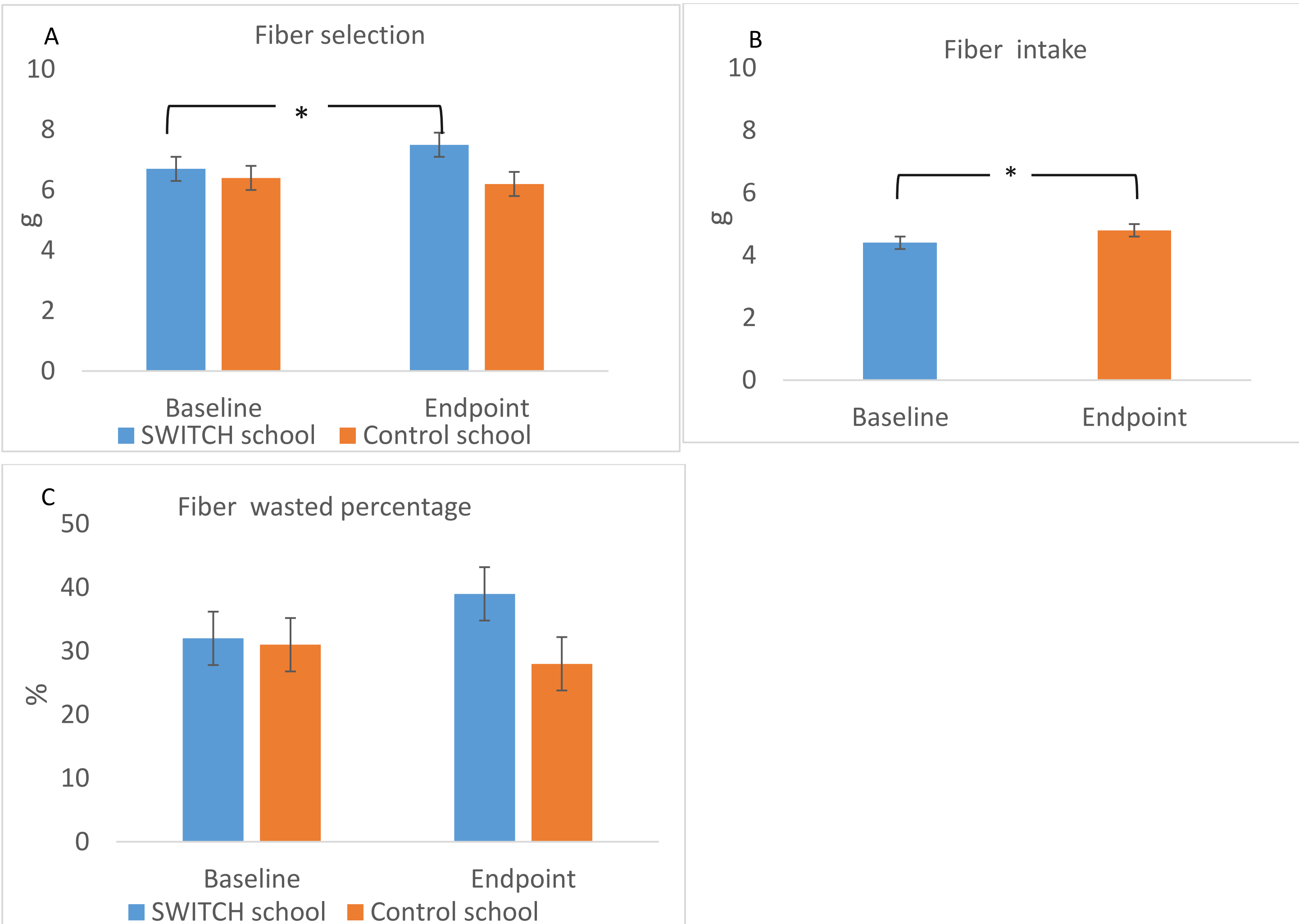


Figure 5.4. Fiber selection, intake and wasted percentage. (* represents significant difference, p<0.05). A: Fiber selection. B: Fiber intake. C: Fiber wasted percentage.

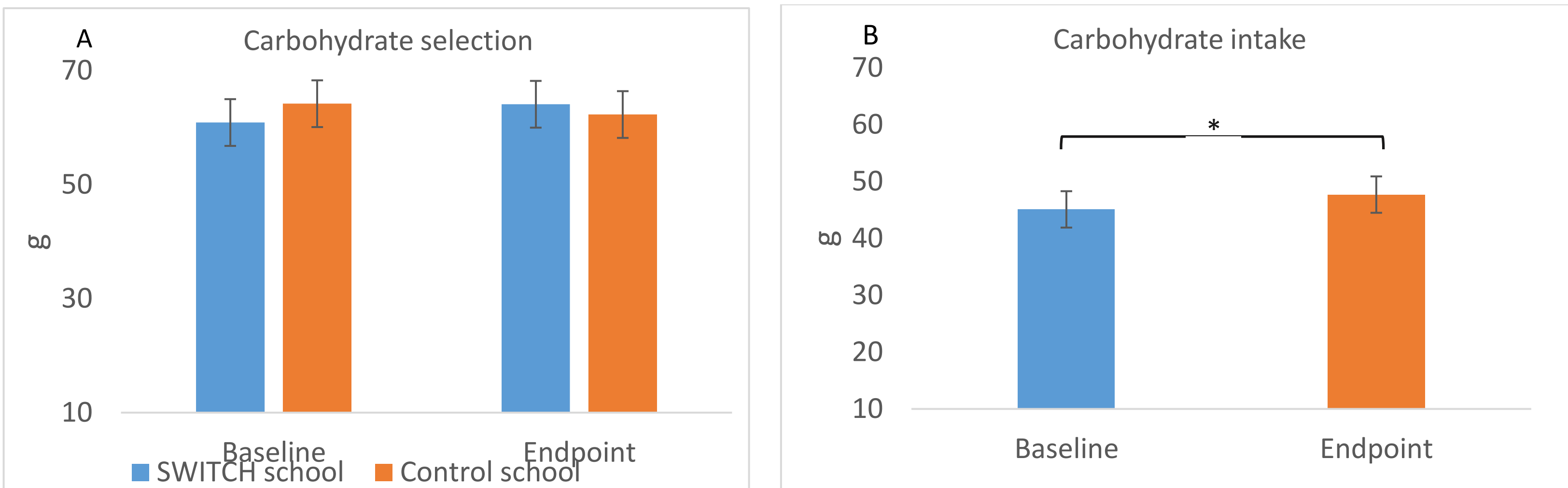


Figure 5.5. Carbohydrate selection and intake. (* represents significant difference, $p<0.05$)
A: Carbohydrate selection. B: Carbohydrate intake (averaged over all schools in all measurement days).

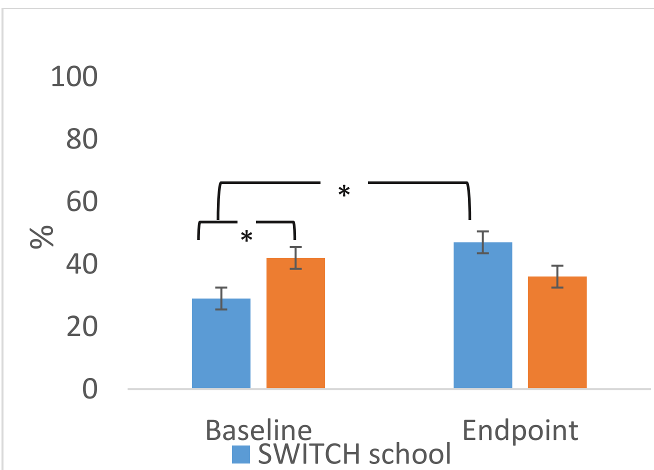


Figure 5.6. Percentage of students meeting the energy recommendation. (* represents significant difference, $p<0.05$)

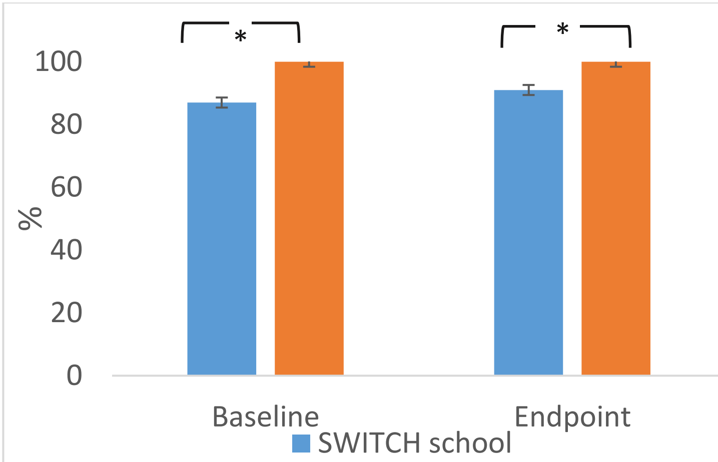


Figure 5.7. Percentage of students meeting the sodium recommendation. (* represents significant difference, p<0.05)

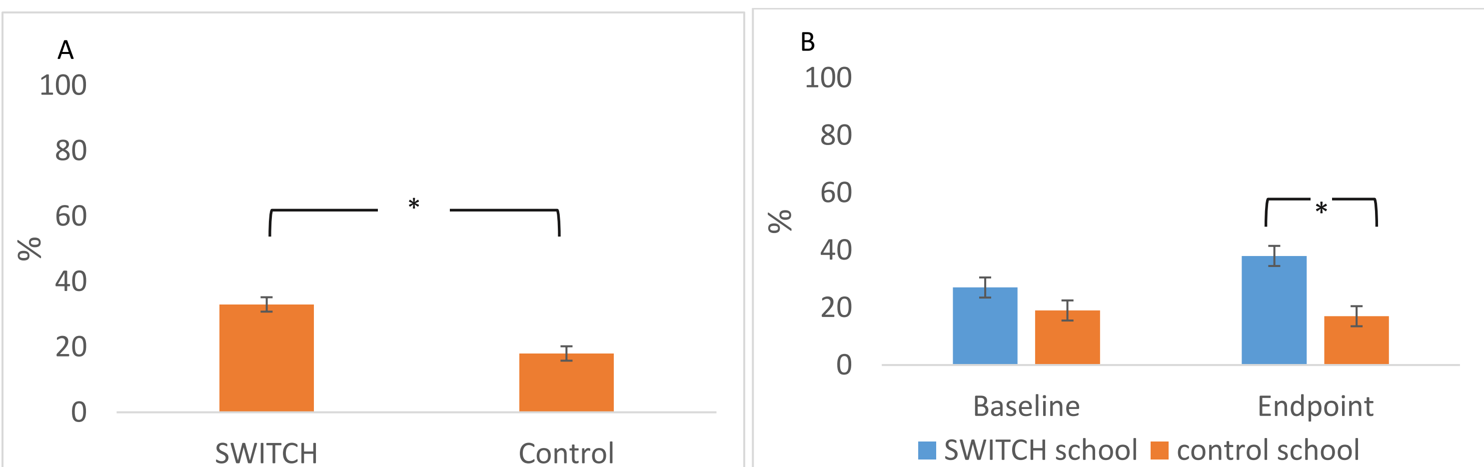


Figure 5.8. Percentage of students meeting the fiber recommendation. (* represents significant difference, p<0.05)
A: Percentage comparing between SWITCH and control schools (averaged across baseline and endpoint).
B: Percentage comparing between SWITCH and control schools at baseline and endpoint.

CHAPTER 6 GENERAL CONCLUSIONS

Valid and reliable dietary assessment methods provide insights to understand people's dietary behaviors and intakes. Particularly in the context of the pediatric obesity epidemic, dietary assessments play a vital role in helping the weight management of children and adolescents. Compared to some traditional self-reported dietary assessments that are commonly used in adults, visual estimation methods with unique advantages have developed rapidly, especially with advances in digital technologies. The photo-based visual estimation method was first described in detail by Williamson and colleague (2002), and was shown to be valid and reliable in a later publication by the same research team (2003) through comparing to the direct weighing method and on-site visual estimation method.[1,2] Since then, it has been widely applied in studies to investigate children's dietary patterns and food/nutrient intakes, or to evaluate the impacts of some programs on promoting children's healthy eating. In a review paper which systematically summarized the plate waste studies conducted in NSLP from 1978 to 2015, visual estimation methods including both on-site and photo-based were applied in 22 out of 45 total studies.[3] Various rating scales were used in different studies to estimate the percentage of food waste/consumption. However, validity and reliability of commonly-used visual estimation rating scales have not yet been systematically assessed by taking into account the influence of specific personal- or food-related factors. Such research gaps may bring confusion to the diet assessment area and hinder the further applications of visual estimation methods.

To fill the research gaps and expand the range of possible applications, three studies were designed and presented in this dissertation. In the study "Comparison of Four Different Photo-Based Food Visual Estimation Methods Based on Influencing Factors" (Chapter 3), a photo-based online survey was developed and sent to the entire community of a large mid-west university. The participants were asked to estimate food waste using the Third, Quarter, Eighth, and Continuous systems separately and information related to age, gender, height and weight, and major/job background were collected to explore their influence on visual estimations. Least square means of RMSE were calculated and used as the indicator for the accuracy of each visual estimation system. Without considering the various influencing factors, results showed the Quarter and Eighth systems were more accurate than the Third and Continuous systems. There was no significant difference of RMSEs between the Quarter and Eighth systems. About 60% of the survey participants selected the Quarter system as their preferred method in visual estimations. In the Quarter and Third systems, gender had a significant influence: the female population had significantly lower RMSE than the male population indicating the higher accuracy of estimations in females. A quadratic relationship was observed between age and the RMSE across the four systems, and people around the age of 41 were calculated to have the highest estimation accuracy. The RMSEs of people with different BMI categories were slightly different, however, not statistically significant. The background/education related to food and nutrition may enhance the visual estimation accuracy, especially when using the Quarter and Continuous systems. The food types exerted a significant influence on visual estimations: the RMSE was lowest in liquid food, followed by solid food, and then amorphous food. When using the Quarter and Eighth systems, a quadratic relationship between wasted percentage and RMSE was found, indicating food either wasted a little or wasted most could be estimated more accurately.

According to the results from Chapter 3, although different factors may influence the four visual estimation systems differently, overall, the Quarter and Eighth systems are more accurate than the other two. Also considering people's preference, the Quarter system was finally selected and applied in Chapters 4 and 5 to detect the effects of SWITCH programming on students' dietary behaviors and nutrient intakes during school lunch. Before- and after-eating photos were taken for lunch trays of 5th grade students from four elementary schools, two of them participating in SWITCH. In Chapter 4, we focused on the investigation of selection, waste and consumption of fruits and vegetables. Results showed that SWITCH did not decrease the overall food wasted percentage, however, it may have positively impact the fruit consumption. Compared to the slight decrease of fruit consumption in control schools, students in the SWITCH schools significantly increased fruit consumption by increasing their selection amounts. The influence of SWITCH on vegetable selection, waste, and consumption was not significant. The influence of gender on consumption patterns were different between fruit and vegetable: males selected more fruit, but also wasted more, so the consumption was similar as females; males selected much less vegetable, although they wasted less, their consumption was still lower than females. Slicing some fruit or vegetable items might be an effective strategy to increase the consumption, either through increasing selection (such as slicing oranges), or through decreasing waste (such as slicing apples).

The study in Chapter 4 provided evidence to support the SWITCH program as a promising school wellness initiative to enhance children's healthy eating, especially fruits and vegetables. After obtaining the nutrition information for menu items, the energy and nutrient selection, waste, and consumption were further analyzed in Chapter 5, indicating the actual nutrition status during school lunches by comparing to the 2010 IOM recommendations. Without the inclusions of energy and nutrient content in milk, significant decreases in sodium selection and intake, increase in fiber selection, and increase in carbohydrate selection were observed in the SWITCH schools from baseline to endpoint. If including the energy and nutrients contained in milk to calculate the total energy and nutrient intakes, it showed that SWITCH programming increased the percentages of students who met the 2010 IOM recommendations for fiber and energy. Therefore, the results in Chapter 5 provided further support for SWITCH to demonstrate its positive influence on improving students' nutrition status during school lunches, especially decreasing sodium intake and increasing fiber intake.

Taken together, the three studies in this dissertation focused on the methodology of the photo-based visual estimation method and its applications in the SWITCH program. Figure 6.1 demonstrates the key points in each study and the relationships among them. The study regarding the influence of rating scales and various personal- and food-related factors on visual estimations in Chapter 3 not only provides the guidance for rating scale selection used in Chapter 4 and 5, but may lay a foundation for further research as well. Multiple previous research studies showed the effectiveness of trainings on enhancing the visual estimation accuracy.[4–9] The effectiveness and efficiency of training could be further improved, if we obtain more information regarding the characteristics of the rating scale and the target population (such as their age or professional background). The advantages of visual estimation, such as high flexibility and being less burdensome, make it possible to be applied in large-scale plate waste studies in schools. Therefore, training school food service personnel how to use photo-based visual estimations needs to be further studied to help schools better perform plate waste studies to understand their students' nutrition status, and to provide guidance for improvement of school meal quality.

Figures

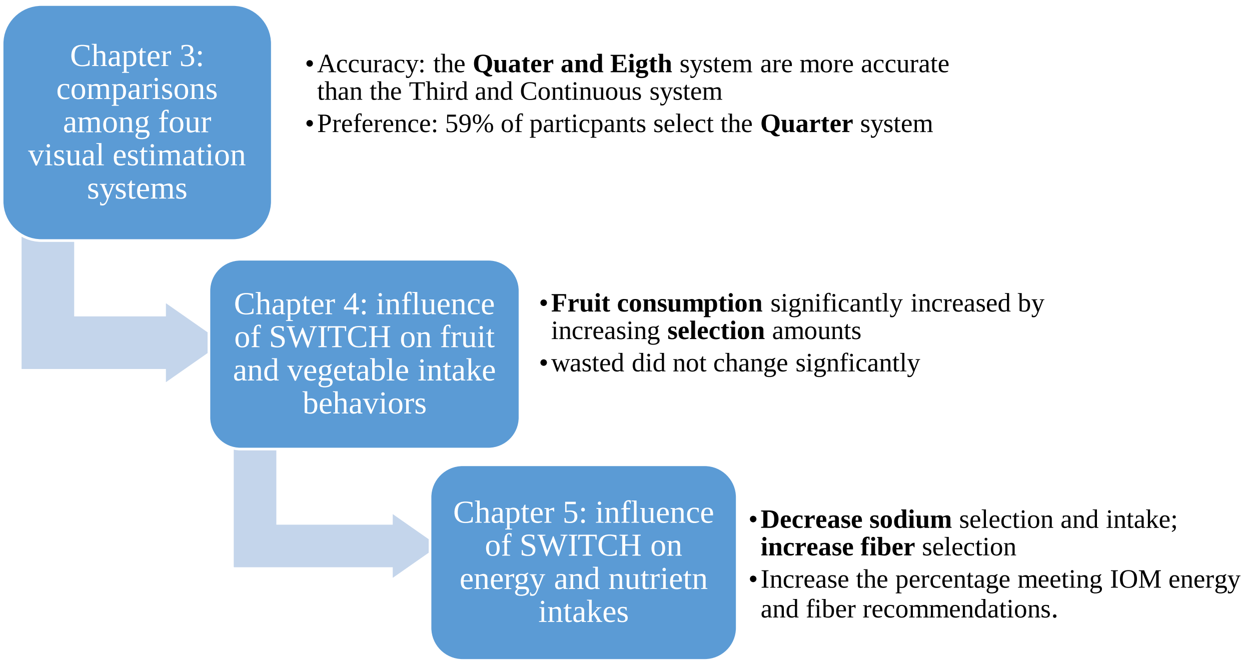


Figure 6.1 Summary of three studies in this dissertation.

References

1. Williamson DA, Pamela ;, Martin D, et al. *Changes in Food Intake and Body Weight Associated with Basic Combat Training*. Vol 167.; 2002. https://academic.oup.com/milmed/article-abstract/167/3/248/4819905. Accessed September 13, 2018.

2. Williamson DA, Allen HR, Martin PD, Alfonso AJ, Gerald B, Hunt A. Comparison of digital photography to weighed and visual estimation of portion sizes. *J Am Diet Assoc*. 2003;103(9):1139-1145. doi:10.1016/S0002-8223(03)00974-X.

3. Byker Shanks C, Banna J, Serrano EL. Food Waste in the National School Lunch Program 1978-2015: A Systematic Review. *J Acad Nutr Diet*. 2017;117(11):1792-1807. doi:10.1016/j.jand.2017.06.008.

4. Bolland JE, Ward JY, Bolland TW. Improved accuracy of estimating food quantities up to 4 weeks after training. *J Am Diet Assoc*. 1990;90(10):1402-1404, 1407.

5. Masis N, McCaffrey J, Johnson SL, Chapman-Novakofski K. Design and Evaluation of a Training Protocol for a Photographic Method of Visual Estimation of Fruit and Vegetable Intake among Kindergarten Through Second-Grade Students. *assessmentJ Nutr Educ Behav*. 2017;49:346-351. doi:10.1016/j.jneb.2017.01.004.

6. Yuhas JA, Bolland JE, Bolland TW. The impact of training, food type, gender, and container size on the estimation of food portion sizes. *J Am Diet Assoc*. 1989;89(10):1473-1477.

7. Bolland JE, Yuhas JA, Bolland TW. Estimation of food portion sizes: effectiveness of training. *J Am Diet Assoc*. 1988;88(7):817-821.

8. WEBER JL, TINSLEY AM, HOUTKOOPER LB, LOHMAN TG. Multimethod Training Increases Portion-Size Estimation Accuracy. *J Am Diet Assoc*. 1997;97(2):176-179. doi:10.1016/S0002-8223(97)00046-1.

9. Riley WT, Beasley J, Sowell A, Behar A. Effects of a Web-based Food Portion Training Program on Food Portion Estimation. *J Nutr Educ Behav*. 2007;39:70-76. doi:10.1016/j.jneb.2006.08.028.

APPENDIX A. THE RECOMMENDATIONS FOR SCHOOL LUNCH IN NATIONAL SCHOOL LUNCH PROGRAM

	Breakfast			Lunch		
	Grades K–5	Grades 6–8	Grades 9–12	Grades K–5	Grades 6–8	Grades 9–12
Meal Pattern	Amount of Foods[a] Per Week					
Fruits (cups)[b]	5	5	5	2.5	2.5	5
Vegetables (cups)[b]	0	0	0	3.75	3.75	5
Dark green	0	0	0	0.5[c]	0.5[c]	0.5[c]
Orange	0	0	0	0.5[c]	0.5[c]	0.5[c]
Legumes	0	0	0	0.5[c]	0.5[c]	0.5[c]
Starchy	0	0	0	1	1	1
Other	0	0	0	1.25[c]	1.25[c]	2.5[c]
Grains, at least half of which must be whole grain-rich[d] (oz eq)	7–10	8–10	9–10	9–10	9–10	12–13
Meats, beans, cheese, yogurt (oz eq)	5	5	7–10	8–10	9–10	10–12
Fat-free milk (plain or flavored) or low-fat milk (1% milk fat or less) (cups)	5	5	5	5	5	5
Other Specifications	Other Specifications: Daily Amount Based on the Average for a 5-Day Week					
Min-max calories (kcal)[e,f]	350–500	400–550	450–600	550–650	600–700	750–850
Saturated fat (% of total calories)[g]	< 10	< 10	< 10	< 10	< 10	< 10
Sodium (mg)	[≤ 430]	[≤ 470]	[≤ 500]	[≤ 640]	[≤ 710]	[≤ 740]
	Sodium targets are to be reached by the year 2020.[h]					
trans fat	Nutrition label must specify zero grams of *trans* fat per serving.[i]					

Source: The table is from School Meals: Building Blocks for Healthy Children (Stallings VA, Suitor CW, Taylor CL, 2010)

APPENDIX B. A PHOTO-BASED ONLINE FOOD WASTE VISUAL ESTIMATION SURVEY

IOWA STATE UNIVERSITY

*Welcome to the **study of factors related to the visual estimation of food amount**! This study aims to explore the influence of some factors which will affect people's food consumption/waste estimation. You will be asked to use different methods (Third-system, Quarter-system, Eighth-system and Continuous system) to estimate how much food is wasted according to the pictures that will be shown to you. Instructions and examples about these different estimation methods will be provided before each estimation section. There is a total of 4 sections and each section contains 7 pictures. At the end, some additional information about you will be collected including your: age, gender, weight, and major. The total amount of time to complete the survey would be 10-15 minutes. You must be 18 years of age or older to participate in this survey.*

None of the information collected will be matched to participants and all the information collected will be kept confidential during and after the survey. No names or identifying factors will be included in any reports of the study results. Your participation is completely voluntary and you can stop the survey at any time without penalty or negative consequences. At the end of survey, we will ask for your email address for a drawing. Three participants will be selected through the drawing to receive a $25 gift card per person. Your email address will be collected on a separate sheet without linking to other parts of the data. After the drawing is completed, the sheet of email lists will be destroyed immediately and the email address will not be used as identifiers or linked to any participants. If you want to participate the drawing, please leave your email address. If you feel uncomfortable to participate in the drawing, you can skip the drawing without any penalty or negative consequences.

*If you have any questions about this survey or this study, please contact **Yuanying Lou** (ylou@iastate.edu) **or Dr. Lorraine Lanningham-Foster** (lmlf@iastate.edu). If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, Office for Responsible Research, 2420 Lincoln Way, Suite 202, Ames, IA 50014, 515-294-1516.*

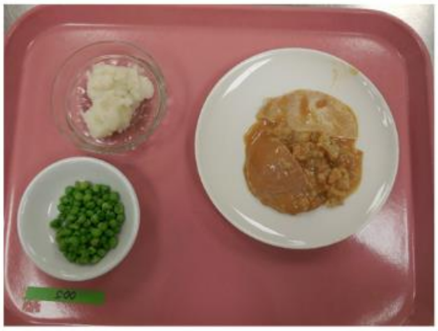
We appreciate your participation very much!

Third system

Instruction--***Third system*** **to estimate food** **<u>Waste</u>:**

Use how many third(s) that was **<u>left</u>** to indicate the food waste. Choose the closest number to estimate. Here is an example:

Before consumption: **After** consumption:



Turkey is two thirds (2/3) left. Mash potato is two thirds (2/3) left. Pea is nothing left (only a few pieces left, so counted as 0). So choose the answer like this:

	Nothing left	1/3 left	2/3 left	All left
Turkey	○	○	●	○
Pea	●	○	○	○
Mash Potato	○	○	●	○

Are you ready? Let's get started!

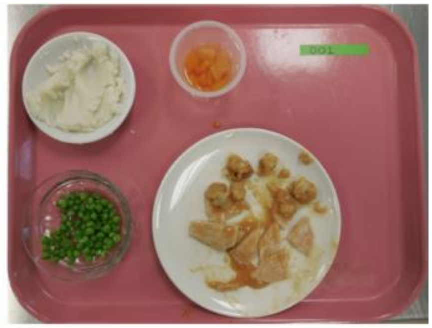
Please estimate how much is **left** using **Third system** for each of the food item:

Before consumption: **After** consumption

	Nothing left	1/3 left	2/3 left	All left
Fish stick	○	○	○	○
Pudding	○	○	○	○
Mac&cheese	○	○	○	○

Please estimate how much is **left** using T**hird system** for each of the food item:

Before consumption: **After** consumption



	Nothing left	1/3 left	2/3 left	All left
Turkey	○	○	○	○
Pea	○	○	○	○
Mash potato	○	○	○	○
Fruit cup	○	○	○	○

Please estimate how much is **left** using **Third system** for each of the food item:

Before consumption: **After** consumption

	Nothing left	1/3 left	2/3 left	All left
Chicken nuggets	○	○	○	○
Mac&Cheese	○	○	○	○
Corn	○	○	○	○
Fruit cup	○	○	○	○

Please estimate how much is **left** using T**hird system** for each of the food item:

Before consumption:

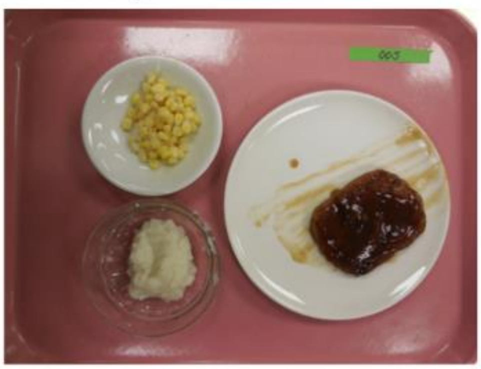
After consumption

	Nothing left	1/3 left	2/3 left	All left
Spaghetti	○	○	○	○
Popcorn chicken	○	○	○	○

Please estimate how much is **left** using **third system** for each of the food item:

Before consumption:

After consumption



	Nothing left	1/3 left	2/3 left	All left
Steak	○	○	○	○
Corn	○	○	○	○
Mash potato	○	○	○	○

Please estimate how much is **left** using T**hird system** for each of the food item:

Before consumption: **After** consumption

	Nothing left	1/3 left	2/3 left	All left
Spaghetti	○	○	○	○
Popcorn chicken	○	○	○	○

Please estimate how much is **left** using **Third system** for each of the food item:

Before consumption: **After** consumption

	Nothing left	1/3 left	2/3 left	All left
Chicken nuggets	○	○	○	○
Mac&Cheese	○	○	○	○
Corn	○	○	○	○

Quarter system

Instruction-- ***Quarter system*** **to estimate food** **<u>Waste</u>**:

Use how many quarter(s) that was **left** to indicate the food waste. Choose the closest number to estimate. Here is an example:

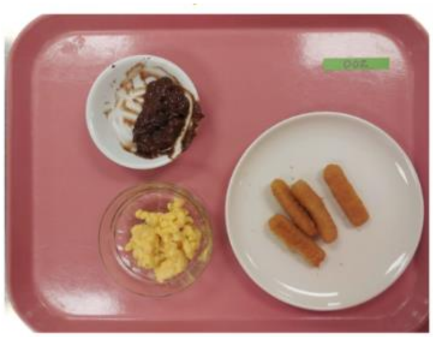
Before consumption: **After** consumption


Turkey is three quarters (3/4) left. Mash potato is half left (1/2). Pea is nothing left (only a few pieces left, so counted as 0). You may choose the answer like this:

	Nothing left	1/4 left	1/2 left	3/4 left	All left
Turkey	○	○	○	◉	○
Pea	◉	○	○	○	○
Mash Potato	○	○	◉	○	○

Please estimate how much is **left** using **Quarter system** for each of the food item:

Before consumption: **After** consumption




	Nothing left	1/4 left	1/2 left	3/4 left	All left
Fish stick	○	○	○	○	○
Mac& cheese	○	○	○	○	○
Pudding	○	○	○	○	○

Please estimate how much is **left** using **Quarter system** for each of the food item:

Before consumption: **After** consumption

	Nothing left	1/4 left	1/2 left	3/4 left	All left
Turkey	○	○	○	○	○
Mash potato	○	○	○	○	○
Pea	○	○	○	○	○
Fruit cup	○	○	○	○	○

Please estimate how much is **left** using **Quarter system** for each of the food item:

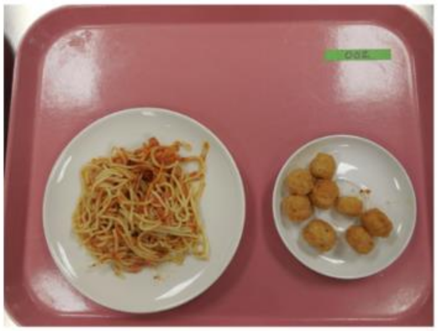
Before consumption: **After** consumption

Hint: there are two parts of Mac& cheese left. Please estimate the **total waste**.

	Nothing left	1/4 left	1/2 left	3/4 left	All left
Chicken Nuggets	○	○	○	○	○
Mac& Cheese	○	○	○	○	○
Corn	○	○	○	○	○
Fruit cup	○	○	○	○	○

Please estimate how much is **left** using **Quarter system** for each of the food item:

Before consumption: **After** consumption



(Hint:there are several pieces of popcorn chicken left over the spaghetti. Please look carefully and estimate the **total waste**!)

	Nothing left	1/4 left	1/2 left	3/4 left	All left
Spaghetti	○	○	○	○	○
Popcorn chicken	○	○	○	○	○

Please estimate how much is **left** using **Quarter system** for each of the food item:

Before consumption: **After** consumption

	Nothing left	1/4 left	1/2 left	3/4 left	All left
Steak	○	○	○	○	○
Corn	○	○	○	○	○
Mash potato	○	○	○	○	○

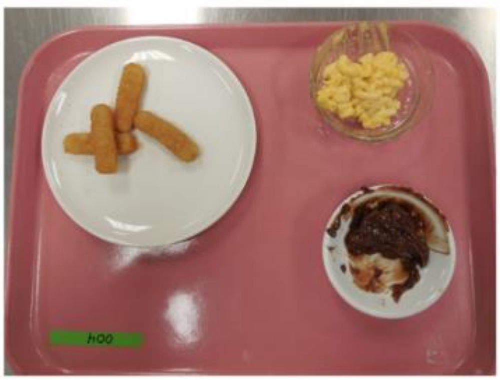
Please estimate how much is **left** using **Quarter system** for each of the food item:

Before consumption: **After** consumption

	Nothing left	1/4 left	1/2 left	3/4 left	All left
Spaghetti	○	○	○	○	○
Popcorn chicken	○	○	○	○	○

Please estimate how much is **left** using **Quarter system** for each of the food item:

Before consumption: **After** consumption



Hint: There are two parts of Mac& and Cheese, please estimate the **total** waste

	Nothing left	1/4 left	1/2 left	3/4 left	All left
Fish stick	○	○	○	○	○
Pudding	○	○	○	○	○
Mac&cheese	○	○	○	○	○

Eighth system

Instruction --*Eighth system* to estimate food <u>Waste</u>:

Use how many eighth(s) that was **left** to indicate the food waste. Choose the closest number to estimate. Here is an example:

Before consumption: **After** consumption

Turkey is five eighth (5/8) left. Mash potato is five eighth left (5/8). Pea is nothing left (only a few pieces left, so counted as 0). You may choose the answer like this:

	Nothing left	1/8 left	2/8 left	3/8 left	4/8 left	5/8 left	6/8 left	7/8 left	All left
Turkey	○	○	○	○	○	●	○	○	○
Pea	●	○	○	○	○	○	○	○	○
Mash Potato	○	○	○	○	○	●	○	○	○

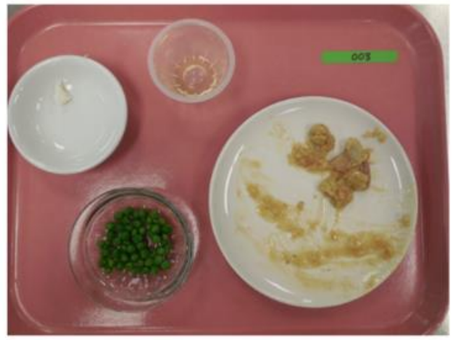
Please estimate how much is **left** using **Eighth system** for each of the food item:

Before consumption: **After** consumption

	Nothing left	1/8 left	2/8 left	3/8 left	4/8 left	5/8 left	6/8 left	7/8 left	All left
Fish stick	○	○	○	○	○	○	○	○	○
Pudding	○	○	○	○	○	○	○	○	○
Mac& Cheese	○	○	○	○	○	○	○	○	○

Please estimate how much is **left** using **Eighth system** for each of the food item:

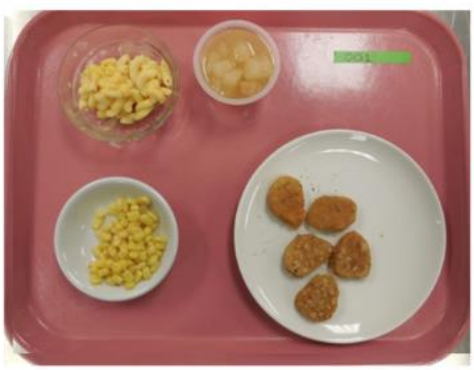
Before consumption: **After** consumption



	Nothing left	1/8 left	2/8 left	3/8 left	4/8 left	5/8 left	6/8 left	7/8 left	All left
Turkey	○	○	○	○	○	○	○	○	○
Pea	○	○	○	○	○	○	○	○	○
Mash Potato	○	○	○	○	○	○	○	○	○
Fruit cup	○	○	○	○	○	○	○	○	○

Please estimate how much is **left** using **Eighth system** for each of the food item:

Before consumption: **After** consumption



	Nothing left	1/8 left	2/8 left	3/8 left	4/8 left	5/8 left	6/8 left	7/8 left	All left
Chicken nuggets	○	○	○	○	○	○	○	○	○
Corn	○	○	○	○	○	○	○	○	○
Mac& Cheese	○	○	○	○	○	○	○	○	○
Fruit cup	○	○	○	○	○	○	○	○	○

Please estimate how much is **left** using **Eighth system** for each of the food item:

Before consumption:

After consumption

*(Hint:there are several pieces of popcorn chicken left over the spaghetti. Please look carefully and estimate the **total waste**!)*

	Nothing left	1/8 left	2/8 left	3/8 left	4/8 left	5/8 left	6/8 left	7/8 left	All left
Spaghetti	○	○	○	○	○	○	○	○	○
Popcorn Chicken	○	○	○	○	○	○	○	○	○

Please estimate how much is **left** using **Eighth system** for each of the food item:

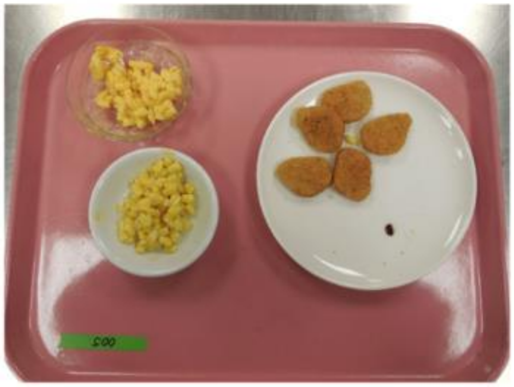
Before consumption:

After consumption

	Nothing left	1/8 left	2/8 left	3/8 left	4/8 left	5/8 left	6/8 left	7/8 left	All left
Steak	○	○	○	○	○	○	○	○	○
Corn	○	○	○	○	○	○	○	○	○
Mash potato	○	○	○	○	○	○	○	○	○

Please estimate how much is **left** using **Eighth system** for each of the food item:

Before consumption: **After** consumption



	Nothing left	1/8 left	2/8 left	3/8 left	4/8 left	5/8 left	6/8 left	7/8 left	All left
Chicken nuggets	○	○	○	○	○	○	○	○	○
Corn	○	○	○	○	○	○	○	○	○
Mac& Cheese	○	○	○	○	○	○	○	○	○

Please estimate how much is **left** using **Eighth system** for each of the food item:

Before consumption: **After** consumption:

	Nothing left	1/8 left	2/8 left	3/8 left	4/8 left	5/8 left	6/8 left	7/8 left	All left
Turkey	○	○	○	○	○	○	○	○	○
Pea	○	○	○	○	○	○	○	○	○
Mash Potato	○	○	○	○	○	○	○	○	○
Fruit cup	○	○	○	○	○	○	○	○	○

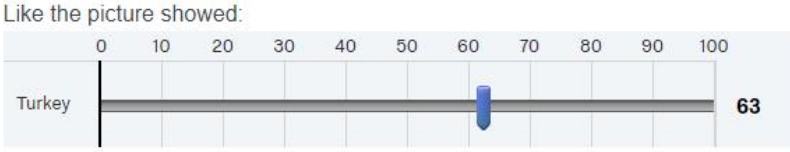
Continuous system

Instruction -- ***Continuous system*** **to estimate food** **<u>Waste</u>:**

Dragging the sliding bar to indicate how much (percentage) of the food that was **left**. Use your best judgment to estimate. Here is an example:

Before consumption: **After** consumption

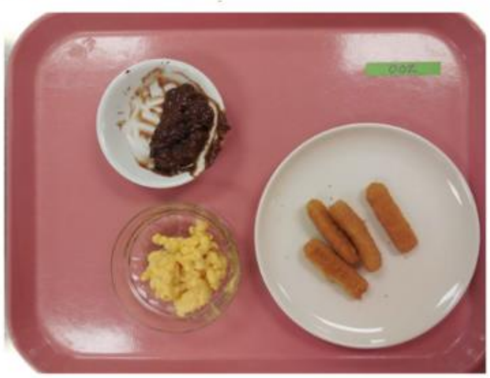
If you think the turkey is about 63% left, please drag the sliding bar to that particular percentage. Like the picture showed:

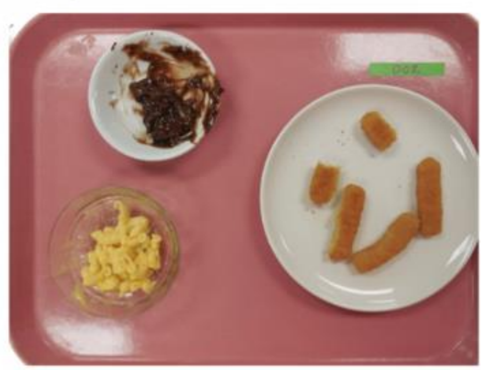


Let's try this method!

Please use sliding bar to indicate how much was **left** for each food item in the picture:

Before consumption: **After** consumptior





Please use sliding bar to indicate how much was **left** for each food item in the picture:

Before consumption:

After consumption

0 10 20 30 40 50 60 70 80 90 100

Turkey

Pea

Mash potato

Fruit cup

Please use sliding bar to indicate how much was **left** for each food item in the picture:

Before consumption:

After consumption

0 10 20 30 40 50 60 70 80 90 100

Chicken Nuggets

Mac& Cheese

Corn

Fruit cup

Please use sliding bar to indicate how much was **left** for each food item in the picture:

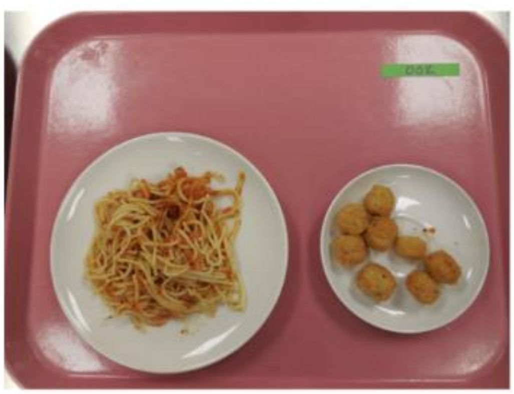
Before consumption:

After consumption

	0	10	20	30	40	50	60	70	80	90	100
Steak											
Mash Potato											
Corn											

Please use sliding bar to indicate how much was **left** for each food item in the picture:

Before consumption:

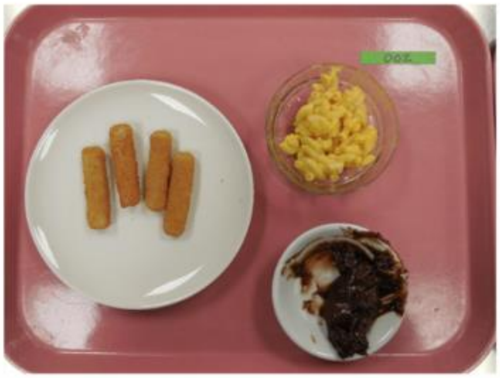


After consumption

	0	10	20	30	40	50	60	70	80	90	100
Spaghetti											
Popcorn Chicken											

Please use sliding bar to indicate how much was **left** for each food item in the picture:

Before consumption:



After consumption

0 10 20 30 40 50 60 70 80 90 100

Fish stick

Mac&Cheese

Pudding

Please use sliding bar to indicate how much was **left** for each food item in the picture:

Before consumption:

After consumption

0 10 20 30 40 50 60 70 80 90 100

Turkey

Pea

Mash potato

Fruit cup

Background information

Thanks so much for your participation! We appreciate your time and efforts on this a lot! Next we will collect some background/personal information. None of the information will be used to match to the participants and all the information collected will be kept confidential during and after the survey. You can skip any questions if you feel uncomfortable.

Your gender:

- ○ Male
- ○ Female
- ○ Other

Your age in years:

Your Height

Inch

OR cm.

Your weight:

lb.

OR kg.

Your major or job area information: (such as physics, business, design, etc.)

In the future estimation, which method would you most likely to use?

Which method you least likely to use?

Would you like to participate in the drawing to have the chance to win a $25 gift card? If your answer is "Yes", you will be directed to a separate page to collect your email address, which will not be linked to the other parts of the survey.

- ◯ Yes
- ◯ No

APPENDIX C. INSTITUTIONAL REVIEW BOARD APPROVAL: FACTORS RELATED TO VISUAL ESTIMATION OF FOOD AMOUNT

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
2420 Lincoln Way, Suite 202
Ames, Iowa 50014
515 294-4566

Date: 2/23/2017

To: Yuanying (Ivy) Lou
220 Mackay Hall

CC: Dr. Lorraine Lanningham-Foster
220 MacKay Hall

From: Office for Responsible Research

Title: Factors related to visual estimation of food amount

IRB ID: 17-078

Study Review Date: 2/23/2017

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

- (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey or interview procedures with adults or observation of public behavior where
  - Information obtained is recorded in such a manner that human subjects cannot be identified directly or through identifiers linked to the subjects; or
  - Any disclosure of the human subjects' responses outside the research could not reasonably place the subject at risk of criminal or civil liability or be damaging to their financial standing, employability, or reputation.

The determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**
- **You must carry out the research as described in the IRB application.** Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any modifications to the research procedures (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the inclusion of participants from vulnerable populations, and/or any change that may increase the risk or discomfort to participants. Changes to key personnel must also be approved. The purpose of review is to determine if the project still meets the federal criteria for exemption.

  Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

  Detailed information about requirements for submission of modifications can be found on the Exempt Study Modification Form. A Personnel Change Form may be submitted when the only modification involves changes in study staff. If it is determined that exemption is no longer warranted, then an Application for Approval of Research Involving Humans Form will need to be submitted and approved before proceeding with data collection.

Please note that you must submit all research involving human participants for review. **Only the IRB or designees may make the determination of exemption**, even if you conduct a study in the future that is exactly like this study.

Please be aware that **approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **An IRB determination of exemption in no way implies or guarantees that permission from these other entities will be granted.**

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

APPENDIX D. MAJOR CATEGORIES USED IN THE SURVEY

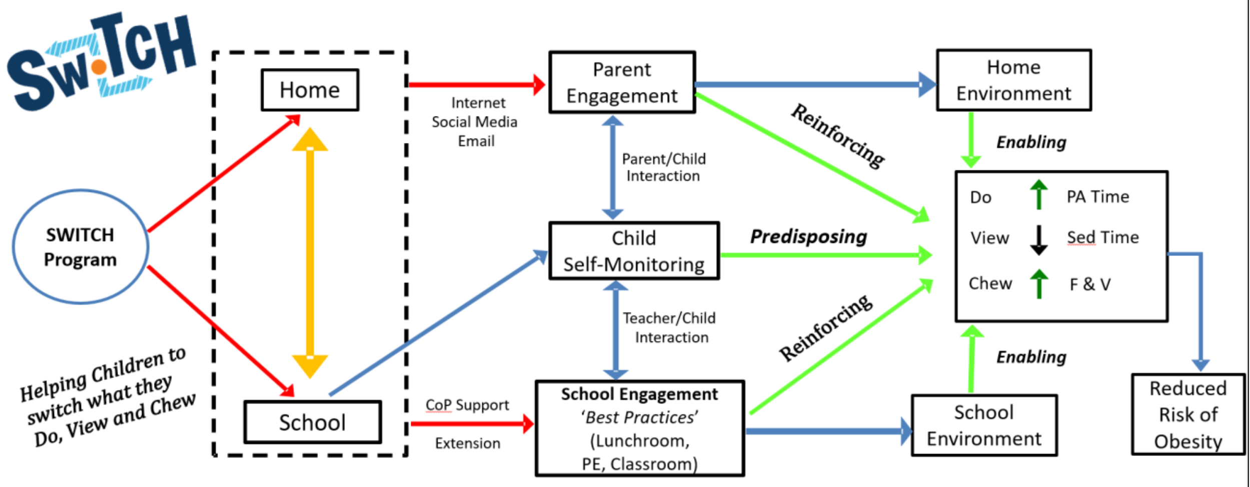
Major/Job category	Majors/Jobs included
Food/Nutrition-related	cooking and nutrition and exercise, diet and exercise, dietetics, dining, food safety, food science, food service, hospitality management, nutritional science, kinesiology, nutrition and wellness, nutrition care
Design-related	apparel design, apparel merchandising, apparel/events/hospitality management, architecture, design, graphic art, graphic design, industrial design, landscape architecture, pre-interior design, web design
Engineering-related	aerospace engineering, agricultural and biosystems engineering, chemical engineering, civil engineering, electronic engineering, computer engineering, mechanical engineering, materials engineering, industrial engineering, software engineering, engineering and technology
Natural science-related	agriculture, agronomy, animal science, animal ecology, biochemistry, bioinformatics, biology, biomedical science, chemistry, ecology, environmental science, forestry, genetics, mathematics, meat science, medicine, microbiology, molecular biology, physics, plant biology, statistics, veterinary medicine, zoology
Others	Any other major not mentioned above

APPENDIX E. THE CATEGORIZATION OF FOOD ITEMS USED IN THE SURVEY

Food	Type [1]
Fish stick	1
Chicken Nugget	1
Popcorn Chicken	1
Beef steak	1
Chocolate pudding	2
Mac &Cheese	2
Turkey breast	2
Green peas	2
Mash potato	2
Sweet corns	2
Spaghetti	2
Fruit cup	3

Note: 1. Type 1 include the food with certain shape or food that is countable.
Type 2 include amorphous food or food that is uncountable.
Type 3 include liquid/semi-liquid food.

APPENDIX F. THE LOGIC MODEL OF THE SWITCH PROGRAM



Target	Process Measures	Mediators	Outcome Measures
Parent	Web Access / Clicks	Interactions	FNPA Survey
Child	Trackers	Correlates *	YAP Survey (Do, View, Chew)
School	Fidelity Checklists	Interactions	School Change *

APPENDIX G. INSTITUTIONAL REVIEW BOARD APPROVAL: DISSEMINATION OF THE SWITCH PROGRAM

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
2420 Lincoln Way, Suite 202
Ames, Iowa 50014
515 294-4566

Date: 07/05/2018

To: L. Lanningham-Foster

From: Office for Responsible Research

Title: Dissemination of the SWITCH Program

IRB ID: 14-651

Submission Type: Continuing Review & Modification **Review Type:** Expedited

Approval Date: 07/05/2018 **Date for Continuing Review:** 07/04/2019

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, including the recruitment materials and informed consent documents that have the IRB approval stamp.
- **Retain signed informed consent documents** for 3 years after the close of the study, when documented consent is required.
- **Obtain IRB approval prior to implementing** any changes to the study.
- **Inform the IRB if the Principal Investigator and/or Supervising Investigator end their role or involvement with the project** with sufficient time to allow an alternate PI/Supervising Investigator to assume oversight responsibility. Projects must have an eligible PI to remain open.
- **Immediately inform the IRB of (1) all serious and/or unexpected** adverse experiences involving risks to subjects or others; and (2) any other unanticipated problems involving risks to subjects or others.
- **Stop all human subjects research activity if IRB approval lapses,** unless continuation is necessary to prevent harm to research participants. Human subjects research activity can resume once IRB approval is re-established.
- **Submit an application for Continuing Review** at least three to four weeks prior to the date for continuing review as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

IRB 03/2018

APPENDIX H. SCHOOL LUNCH MENU ITEMS ON MEASUREMENT DAYS IN THE STUDY IN CHAPTER 4

	SWITCH school 1				SWITCH school 2			
	Baseline		Endpoint		Baseline		Endpoint	
	Measurement day 1	Measurement day 2	Measurement day 1	Measurement day 2	Measurement day 1	Measurement day 2	Measurement day 1	Measurement day 2
Hot entree	Pepperoni Pizza	Cinnamon Roll, Egg	Pepperoni Pizza	Cinnamon Roll, Egg	Chicken Tenders, Dinner roll	French Toast stick	Chicken Tenders, Dinner roll	French Toast stick
Cold Entree	Turkey Deli roll	Jungle Jag Package	Turkey Deli roll	Jungle Jag Package	Jungle Jag Package	Hondo Hawk Package	Jungle Jag Package	Hondo Hawk Package
Fruit	Apple, Pear, Orange, Banana	Apple, Blueberry, Orange, Banana	Apple, Pear, Orange, Banana	Apple, Blueberry, Orange, Banana	Apple, Orange, Banana	Apple, Orange, Banana, Cherry-Lemon Slushy	Apple, Orange, Banana, Kiwi	Apple, Orange, Banana, Cherry-Lemon Slushy
Vegetable	GoBonzo Bean, Fresh lettuce	Sweet Potato Fries, Fresh Lettuce	GoBonzo Bean, Fresh lettuce	Sweet Potato Fries, Fresh Lettuce	Baked Bean, Fresh lettuce	Sweet Potato Fries, Fresh Lettuce	Baked Bean, Fresh lettuce	Sweet Potato Fries, Fresh Lettuce

	Control school 1				Control school 2			
	Baseline		Endpoint		Baseline		Endpoint	
	Measurement day 1	Measurement day 2	Measurement day 1	Measurement day 2	Measurement day 1	Measurement day 2	Measurement day 1	Measurement day 2
Hot entree	Cinnamon Roll, Egg	Deep dish cheese pizza	Cinnamon Roll, Egg	Deep dish cheese pizza	Popcorn chicken, Dinner roll	French Toast stick	Popcorn chicken, Dinner roll	French Toast stick
Cold Entree	Jungle Jag Package	Hondo Hawk Package	Jungle Jag Package	Hondo Hawk Package	Hondo Hawk Package	Hondo Hawk Package	Hondo Hawk Package	Hondo Hawk Package
Fruit	Apple, Blueberry, Orange, Banana	Apple, Applesauce, Orange, Banana	Apple, Blueberry, Orange, Banana	Apple, Applesauce, Orange, Banana	Apple, Orange, Banana	Apple, Orange, Banana, Cherry-Lemon Slushy	Apple, Orange, Banana	Apple, Orange, Banana, Cherry-Lemon Slushy
Vegetable	Sweet Potato Fries, Fresh Lettuce	Peas, Fresh lettuce	Sweet Potato Fries, Fresh Lettuce	Peas, Fresh lettuce	Baby carrot, Fresh lettuce	Sweet Potato Fries, Fresh Lettuce	Baby carrot, Fresh lettuce	Sweet Potato Fries, Fresh Lettuce

APPENDIX I. MYPLATE STANDARD SERVING SIZES OF FRUITS AND VEGETABLES PROVIDED IN SCHOOL MENUS

Fruit/Vegetable items	MyPlate standard serving size (counted as 1 cup)
Cooked beans	1 cup
Fresh salads (lettuce)	2 cups
Baby carrots	1 cup sliced (about 12)
Sweet potato fries	1 cup
Apple	½ large, or 1 small, or 1 cup sliced
Orange	1 large, or 1 cup sliced
Blueberries	1 cup
Banana	1 large
Applesauce	1 cup
Kiwi	1 medium
Pear	1 cup sliced

APPENDIX J. WASTED PERCENTAGE OF FOOD ESTIMATED IN SWITCH SCHOOLS AND CONTROL SCHOOLS IN CHAPTER 4

Food (category)	Wasted percentage (mean ± SEM)
Kiwi **(fruit)**	81.82 ±6.93
Whole Apple **(fruit)**	60 ± 2
Whole Orange **(fruit)**	59.38 ± 6.63
Apricot **(fruit)**	54.17 ± 13.26
Potato Fries **(cooked vegetable)**	47.97 ± 5.34
Turkey Roll **(cold entrée)**	45.37 ± 8.12
Carrot **(fresh vegetable)**	41.67 ± 5.2
Bean **(fresh vegetable)**	41.55 ± 3.78
Banana **(fruit)**	40.23 ± 3.1
Slushy **(fruit)**	40.05 ± 3.28
Blueberry **(fruit)**	38.24 ± 4.55
Sliced Orange **(fruit)**	37.5 ± 9.37
Salad **(fresh vegetable)**	36.44 ± 1.93
Entrée Package **(cold entrée)**	30.17 ± 3.48
Sliced Apple **(fruit)**	22.95 ± 4.64
Pear **(fruit)**	21.71 ± 5.27
French Toast **(hot entrée)**	20.73 ± 3
Egg **(hot entrée)**	13.17 ± 2.51
Dinner Roll **(hot entrée)**	12.91 ± 2.94
Apple Sauce **(fruit)**	12.02 ± 3.66
Pizza **(hot entrée)**	11.92 ± 2.33
Cinnamon Roll **(hot entrée)**	9.55 ± 2.23
Chicken **(hot entrée)**	7.58 ± 2.61
Peas **(cooked vegetable)**	4.17 ± 13.26

APPENDIX K. THE PERCENTAGE OF STUDENTS WHO DID NOT MEET THE ENERGY AND TOTAL FAT RECOMMENDATIONS IN SWITCH AND CONTROL SCHOOLS.

	Calorie selection < 550 kcal (%) [1]	Calorie selection > 650 kcal (%) [1]	Total fat selection <25 % of total energy selection (%) [1]	Total fat selection >35 % of total energy selection (%) [1]
SWITCH school --baseline	51 ± 3.5	20 ± 3.5	20 ± 0.6	32 ± 0.6
SWITCH school --endpoint	36 ±3.7	16 ±3.7	25 ± 0.6	24 ± 0.6
Control school --baseline	47 ± 3.4	11 ± 3.4	49 ± 0.6	16 ± 0.6
Control school --endpoint	53 ± 3.7	11 ± 3.7	45 ± 0.6	23 ± 0.6

Note: 1. Shown as the percentage of students not meeting the requirement over the total number student ± SEM.