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The Efficacy of a Plant Based Diet in Reducing Metabolic Risk in Overweight or Obese Children

Joo Young Kim
Pacific University

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The Efficacy of a Plant Based Diet in Reducing Metabolic Risk in Overweight or Obese Children

Abstract

**Background:** Metabolic syndrome (MetS) is a group of risk factors associated with cardiovascular disease (CVD) and type II diabetes (T2DM). MetS has been found to be occurring with increasing frequency in younger populations, with overweight or obese children considered to be at greater risk. This special population may benefit from early intervention. The cornerstone of management in MetS is aggressive lifestyle modification typically consisting of diet and exercise. Although little is known regarding optimal dietary management in this population, recent studies suggest that there may be a role in advocating for consumption of plant based foods to reduce metabolic risk. The purpose of this systematic review is to evaluate the available literature and assess the viability of recommending a plant based diet to reduce metabolic risk in overweight or obese children.

**Methods:** A systematic search of the available literature on MEDLINE-Ovid, CINAHL, and Web of Science databases was conducted using the following keywords: *plant based diet*, *children*, and *metabolic risk*. All articles were screened with eligibility criteria for interventions involving significant components of a plant based diet, measures relevant to risk factors for metabolic syndrome, and the use of overweight or obese children as subjects. The relevant studies were then assessed for quality using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) system.

**Results:** The search of the literature resulted in two studies that met eligibility criteria for this systematic review. One was a randomized controlled study (RCT) and the other was a cross sectional study. The RCT reported multiple beneficial reductions from baseline in markers for CVD and T2DM in a group of obese children that were placed on a plant based diet (PBD). The cross sectional study found intake of vegetables to be associated with greater insulin sensitivity (SI), decreased hepatic fat fraction (HFF), and decreased visceral adipose tissue (VAT) in overweight or obese Latino children.

**Conclusion:** The commonly accepted health benefits of a plant based diet (PBD) likely extend to overweight or obese children. Consumption of plant based foods may lead to substantial benefits for this population and are low risk when there is proper education and monitoring to ensure a balanced diet. Further studies regarding long-term health effects of a PBD on overweight or obese children are needed.

**Keywords:** plant based diet, children, metabolic risk.

**Degree Type**
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**Degree Name**
Master of Science in Physician Assistant Studies

**First Advisor**
Mark Pedemonte, MD

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Keywords
plant based diet, children, metabolic risk

Subject Categories
Medicine and Health Sciences

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The student author attests that this work is completely his/her original authorship and that no material in this work has been plagiarized, fabricated or incorrectly attributed.
The Efficacy of a Plant Based Diet in Reducing Metabolic Risk in Overweight or Obese Children

Joo Young Kim

A Clinical Graduate Project Submitted to the Faculty of the
School of Physician Assistant Studies
Pacific University
Hillsboro, OR
For the Masters of Science Degree, August, 2016

Faculty Advisor: David Keene, PA-C, MS

Clinical Graduate Project Coordinator: Annjanette Sommers, PA-C, MS
Biography
Joo Young Kim is the second son of Moses and Young Eun Kim. He was born in Nairobi, Kenya and raised in Kailua Kona, Hawaii. In 2011, he earned his undergraduate degree in Sports Medicine from Pepperdine University. Following graduation, he volunteered at a free clinic as a medical assistant and worked full time as a live in caregiver prior to entering Pacific University.
Abstract

Background: Metabolic syndrome (MetS) is a group of risk factors associated with cardiovascular disease (CVD) and type II diabetes (T2DM). MetS has been found to be occurring with increasing frequency in younger populations, with overweight or obese children considered to be at greater risk. This special population may benefit from early intervention. The cornerstone of management in MetS is aggressive lifestyle modification typically consisting of diet and exercise. Although little is known regarding optimal dietary management in this population, recent studies suggest that there may be a role in advocating for consumption of plant based foods to reduce metabolic risk. The purpose of this systematic review is to evaluate the available literature and assess the viability of recommending a plant based diet to reduce metabolic risk in overweight or obese children.

Methods: A systematic search of the available literature on MEDLINE-Ovid, CINAHL, and Web of Science databases was conducted using the following keywords: plant based diet, children, and metabolic risk. All articles were screened with eligibility criteria for interventions involving significant components of a plant based diet, measures relevant to risk factors for metabolic syndrome, and the use of overweight or obese children as subjects. The relevant studies were then assessed for quality using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) system.

Results: The search of the literature resulted in two studies that met eligibility criteria for this systematic review. One was a randomized controlled study (RCT) and the other was a cross sectional study. The RCT reported multiple beneficial reductions from baseline in markers for CVD and T2DM in a group of obese children that were placed on a plant based diet (PBD). The cross sectional study found intake of vegetables to be associated with greater insulin sensitivity (SI), decreased hepatic fat fraction (HFF), and decreased visceral adipose tissue (VAT) in overweight or obese Latino children.

Conclusion: The commonly accepted health benefits of a plant based diet (PBD) likely extend to overweight or obese children. Consumption of plant based foods may lead to substantial benefits for this population and are low risk when there is proper education and monitoring to ensure a balanced diet. Further studies regarding long-term health effects of a PBD on overweight or obese children are needed.

Keywords: plant based diet, children, metabolic risk.
Acknowledgements

I would like to thank Gary and Ruth Ann Baker, Jeanne Lee, Priscilla MacRae, and Christopher Russell for their invaluable contributions that have helped shape me on my journey. I would also like to thank all the faculty and staff at Pacific University School of Physician Assistant Studies for their dedication to our academic success.

To *my parents*: I am grateful for the unconditional love and support. S.D.G.
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Table I: Characteristics of Reviewed Studies
Table II: Summary of Findings-Macknin et al^{11}
Table III: Summary of Findings-Cook et al^{12}

List of Abbreviations

AHA.................................................................American Heart Association
AIR...............................................................Acute Insulin Response
ANCOVA..........................................................Analysis of Covariance
BMI...............................................................Body Mass Index
CVD.............................................................Cardiovascular Disease
CDC.............................................................Centers for Disease Control and Prevention
DI.................................................................Disposition Index
HDL-C..........................................................High Density Lipoprotein Cholesterol
HgbA1C..........................................................Hemoglobin A1C
HOMA-IR......................................................Homeostasis Model Assessment of Insulin Resistance
hscRP............................................................High-sensitivity C-reactive protein
LDL-C..........................................................Low Density Lipoprotein Cholesterol
MD.............................................................Mediterranean Diet
MPO.............................................................Myeloperoxidase
MetS............................................................Metabolic Syndrome
NAFLD.......................................................Non Alcoholic Fatty Liver Disease
NRV.............................................................Nutrient Rich Vegetables
NSV.............................................................Non Starchy Vegetables
PAQ.............................................................Physical Activity Questionnaire
PBD.............................................................Plant Based Diet
RCT............................................................Randomized Controlled Trial
SAT.............................................................Subcutaneous Abdominal Adipose Tissue
SI.............................................................Insulin Sensitivity
T2DM..........................................................Type II Diabetes Mellitus
TC.............................................................Total Cholesterol
VAT.............................................................Visceral Adipose Tissue

List of Appendices
The Efficacy of a Plant Based Diet in Reducing Metabolic Risk in Overweight or Obese Children

BACKGROUND

Metabolic syndrome (MetS) is a group of risk factors associated with cardiovascular disease and type II diabetes.¹ These two conditions have been listed among the top 10 causes of morbidity and mortality in the United States for many years.² Because cardiovascular disease (CVD) may result in acute coronary syndrome and associated sequelae during the latter years of life, it was once thought to be a disease of older age and excess. It is now commonly known that atherosclerotic disease can begin early in childhood with fatty streaking within vessels, and increased arterial stiffness. Similarly, type II diabetes (T2DM) is differentiated from various other forms including type I diabetes as well as latent autoimmune diabetes, and was linked with older populations. In the last several decades, there has been growing acknowledgement of the increasing prevalence of CVD and T2DM in younger populations with overweight or obese youth considered to be at greater risk.³,⁴

A study⁵ published by the American Diabetes Association reported that in 2012, the total costs to the U.S. healthcare system for diabetes related care was estimated to approach $245 billion. Another study⁶ that compared health care utilization and costs among patients with MetS to those without found that patients with MetS had average annual total costs that were 1.6 times greater. The rising frequency of metabolic disease in younger populations, in addition to the growing economic burden and associated healthcare costs demonstrate the importance of addressing this problem with early intervention in children who are at greater risk.

The details regarding the risk factors for MetS are subject to continued debate. However, the general factors are recognized to be increased insulin resistance, elevated blood pressure, dyslipidemia, and obesity.¹ Because MetS by definition is a group of risk factors and does not
require the presence of disease itself, the cornerstone of management is aggressive lifestyle modification. This usually consists of recommendations regarding diet and exercise.\textsuperscript{7}

Benefits of consuming plant based foods have been well documented; however, the data does not appear to extend to overweight or obese children and there is limited information regarding optimal dietary management in this population.\textsuperscript{8,9} A plant based diet (PBD) is one that strives to avoid processed foods and meat products and instead focuses on whole, plant based foods.\textsuperscript{8} The goal of this systematic review is to examine the available literature to assess current knowledge regarding a PBD in this special population and evaluate whether a PBD would be a viable recommendation based on the results.

**METHODS**

A systematic search of the available literature in MEDLINE-Ovid, CINAHL, and Web of Science databases was conducted using the following keywords: *plant based diet, children*, and *metabolic risk*. All articles were screened to meet eligibility criteria for interventions involving significant components of a plant based diet, measures relevant to risk factors for metabolic syndrome, and the use of overweight or obese children as subjects. The relevant studies were then assessed for quality using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) system.\textsuperscript{10}

**RESULTS**

A systematic search of the literature resulted in 178 articles from MEDLINE-Ovid, zero articles from CINAHL, and four articles from Web of Science. Of the 182 total results, 155 remained after meeting inclusion criteria for articles published in the English language, and containing human subjects. Of the remaining 155 articles, two studies obtained from MEDLINE-
Ovid were found to meet the eligibility criteria. Both studies\textsuperscript{11,12} were published in the last year (2015). See Table I.

\textbf{Macknin et al (2015)}

This prospective randomized 4-week trial\textsuperscript{11} recruited 30 child-parent pairs from pediatric practices of a hospital system in the Midwest to look at whether a PBD and/or American Heart Association (AHA) diet would affect anthropometric measurements and/or markers of inflammation, CVD, and T2DM. There were 1278 participants who met criteria for being between 9-18 years of age with a body mass index greater than the 95\textsuperscript{th} percentile and last total cholesterol (TC) measurement being greater than 169 mg/dL and were initially identified from the medical records of the Cleveland Clinic and invited to join the study.\textsuperscript{11}

Participants were enrolled on a first-come, first-served basis and each child-parent pair received a $50 stipend each week for the duration of the trial. The subjects were stratified by age into a 9-13 year age group and a 14-18 year age group. They were then randomly assigned in blocks of 4 families to either a PBD or AHA diet. There were 16 child-parent pairs in the PBD and 14 pairs in the AHA groups. No significant differences were found between groups in regards to baseline demographic, nutritional, and metabolic markers.\textsuperscript{11}

The subjects were given dietary instructions according to their assigned groups. The PBD group was instructed to limit nuts and avocados, and avoid all animal products and added fat foods. The AHA group was instructed to limit their daily intake of total fat to less than 30\%, saturated fat to less than 7\%, cholesterol to less than 300mg, and dietary sodium to less than 1500mg. The subjects received standardized teaching on how to record a 24-hour dietary history and were required to attend weekly educational sessions on nutrition and cooking. Subjects were required to complete two sets of dietary histories, one prior to the study, and the other during the
study. Each set contained two weekdays and one weekend. Nutritional information was collected and analyzed from the histories. Measurements for height and weight were obtained and used in determining BMI z-scores. Markers for inflammation, CVD, and T2DM were also obtained prior to and at the conclusion of the study. At the beginning and conclusion of the trial the subjects reported their physical activity levels using a Physical Activity Questionnaire (PAQ). Two child-parent pairs from the PBD group were recorded as lost to follow up.¹¹

At the conclusion of the study, both the PBD and AHA groups saw significant changes in mean values for almost all daily nutrient intake measured from baseline. Results were analyzed with a confidence interval of 95% with level of significance set at P<0.01. Additional comparisons done between groups using analysis of covariance (ANCOVA) models with level of significance set at 0.05 found that the PBD group had significantly lower intake of total protein, animal protein, cholesterol, total saturated fat, vitamin D, and vitamin B12 compared to the AHA group.¹¹

BMI z-scores, as well as markers for inflammation, CVD, and T2DM were calculated with a level of significance set at P<0.05. The PBD group saw significant mean decreases from baseline in BMI z-score (from 1.90 to 1.77), weight (from 79.62 to 76.57 kg), systolic blood pressure, mid-arm circumference, total cholesterol, LDL-C, high-sensitivity C-reactive protein (hsCRP), myeloperoxidase (MPO), and fasting insulin levels. The AHA group saw significant mean decreases in weight (from 87.71 kg to 86.16 kg), waist circumference, mid-arm circumference, HDL-C, and MPO. Both groups saw significant mean increases in HgbA1C levels.¹¹ See Table II for PBD group data.

Cook et al (2015)
This cross-sectional study used data from 175 subjects collected between 2006-2011 from five separate studies conducted at the University of Southern California. Linear regression and analysis of covariance were used to look at the relationship between vegetable consumption and metabolic health. Of the five studies, two were observational and three were lifestyle modification programs. Inclusion criteria for the studies were children of Latino descent, who were ages 8-18, overweight or obese (>85th percentile for BMI), absence of any medical conditions or medications that could affect metabolism or body composition, along with sufficient availability of relevant data.

Subjects completed a comprehensive history and physical exam that included height, weight, total body fat, subcutaneous abdominal adipose tissue (SAT), visceral adipose tissue (VAT), and hepatic fat fraction (HFF). A hepatic fat fraction of greater than or equal to 5.5% was classified as non-alcoholic fatty liver disease (NAFLD). Subjects underwent an overnight fast to obtain samples of glucose and insulin the following morning. The samples were further analyzed to examine insulin sensitivity (SI), acute insulin response (AIR), disposition index (DI), and homeostasis model assessment of insulin resistance (HOMA-IR). Dietary intake was recorded via 24 hour recalls using the multiple pass technique. At least two recalls were collected from each subject within a four-week period.

Level of vegetable consumption was classified by quartiles of intake and analyzed in relation to metabolic outcomes. Independent variables included total vegetables, non-starchy vegetables (NSV), nutritionally rich vegetables (NRV), and dietary fiber. NSV included vegetables of dark green, or deep yellow/orange color, as well as other vegetables (beets, cabbage, summer squash, etc.), but excluded any starchy vegetables like white potatoes, corn etc.
Dark green or deep yellow/orange vegetables were subcategorized as nutritionally rich vegetables (NRV).^{12}

Among the results, a positive partial correlation between insulin sensitivity and NRV was the only significant correlation found (r=0.19, P=0.03). Analysis of covariance found a significant association between hepatic fat fraction, total vegetable intake (P=0.03), and NSV intake (P=0.01). Increased intake was associated with decreased hepatic fat fraction. The study also found a significant association between acute insulin response, total vegetable intake, and NSV intake (P=0.01). NRV consumption was unable to be ranked in quartiles due to the low number of subjects with intake of this category. However when comparing consumers to non-consumers, NRV consumers were found to have increased insulin sensitivity (P=0.03), decreased visceral adipose tissue (P=0.01), and decreased acute insulin response (P=0.05).^{12} See Table III.

**DISCUSSION**

The association between intake of plant based foods and lower body weights in children has been previously documented.^{13} The results of both studies^{11,12} in this review point to the likelihood that the established health benefits of a PBD may extend to overweight or obese children. Macknin et al^{11} reported that the PBD group saw a significant mean decrease in fasting insulin levels with the HOMA calculation suggesting decreased insulin resistance. This finding may have been related to the significant mean increase in dietary fiber intake, as well as decreases in total caloric intake and BMI scores, as it is known that obesity and insulin resistance are linked.^{14} Cook et al^{12} reported that NRV consumption was associated with increased insulin sensitivity and decreased visceral adipose tissue. In particular, they reported a significant partial correlation between NRV consumption and increased insulin sensitivity when compared to non-consumers. This correlation remained even after adjusting for a priori covariates including body
fat mass. These findings support the extension of the established link between visceral adipose tissue and insulin resistance to overweight or obese children.

Macknin et al reported that plant based foods appeared to reduce metabolic risk with significant mean improvements in total cholesterol, LDL-C, SBP, and inflammatory biomarkers hsCRP and MPO, which are implicated in metabolic disease. It is also worth mentioning that although the study by Macknin et al was not primarily powered to compare between PBD and AHA groups, the PBD group was found to have a greater number of significant reductions in metabolic outcomes than the AHA group. Cook et al found that higher intakes of NSV were associated with decreased hepatic fat fraction. However, in one possible cause for concern Macknin et al noted a significant mean increase in HgbA1C levels that occurred in both PBD and AHA groups. Although the authors felt that the overall weight of evidence leaned towards a decrease in insulin resistance and fasting insulin levels, it is unclear why both groups saw this increase in HgbA1C levels. The relatively short 4-week intervention does little to shed light on whether the spike may have been transient and related to the marked reduction in total energy intake from baseline.

Macknin et al also found that the PBD group had significant mean decreases from baseline of essential nutrient intake including total protein, vitamin B12, and vitamin D. While it is possible to obtain adequate protein along with the necessary essential amino acids by following a balanced plant based diet, supplementation of vitamins B12 and D, as well as Omega-3 fatty acids are generally recommended. Because of this and other issues, concerns regarding physical growth in children on plant based diets have been addressed, with longitudinal studies of large cohorts generally finding little or no difference in growth among children raised on PBD compared with traditional diets that include meat sources. Although
none of the above mentioned studies were specifically conducted on overweight or obese children, this population may be at an advantage. In theory, the increased body fat mass in overweight or obese children may enable them to temporarily withstand caloric deficits and lower levels of protein intake with less muscle wasting as the metabolic pathways shift to increased utilization of lipid stores while sparing protein. ¹⁹

The greatest concerns regarding this systematic review were primarily methodological due to the relatively small sample sizes and limited number of studies found regarding this topic. Limitations of the studies included lack of a control group, small sample sizes, homogenous populations, and possible presence of confounding variables. ¹¹,¹² The RCT by Macknin et al¹¹ failed to include a control group in their study. They did note that the number of subjects enrolled in the study was powered towards detecting changes from baseline within groups, rather than comparison between groups. Macknin et al¹¹ also failed to mention whether the subjects were screened for significant past medical history or medications that may have affected the outcomes of the study. The cross sectional design of the study by Cook et al¹² prevents any information regarding causal relationships and may overestimate the relationship between vegetable consumption and decreased metabolic risk. The failure to control for physical activity levels in the subjects may have further confounded any significant relationships observed in the study. Both Macknin et al¹¹ and Cook et al¹² also utilized dietary histories completed by the subjects, which may have led to the presence of recall bias.

This systematic review found that a balanced PBD is beneficial in overweight or obese children and results in improved metabolic outcomes. When educating patients regarding a PBD, the health care provider should stress the importance of ensuring intake of an adequate variety of plant based foods. Additionally, supplementation of vitamins B12 and D, along with
omega-3 fatty acids should be recommended. Due to the short follow up periods in the reviewed studies, subsequent studies that are longitudinal in nature may be beneficial in order to account for possible effects over time. This is especially important during the adolescent period as children’s metabolic demands may change during puberty. In regards to concern for the increased HgbA1C found by Macknin et al's additional studies with longer term follow up of HgbA1C levels would be helpful to investigate whether this finding may have been related to the abrupt decrease in caloric intake followed by transient, compensatory hepatic gluconeogenesis. Further studies should also make an effort to control for physical activity levels in participants, along with past medical history and medication use, as it is well known that these variables have the ability to affect outcomes of interest in MetS.

**CONCLUSION**

As the numbers of overweight or obese children at risk for MetS continue to increase, it appears that consumption of plant based foods may be beneficial in reducing metabolic risk in this population. Both studies included in this systematic review support the extension of the generally accepted health benefits of a PBD to this population. Macknin et al found that children in the PBD group had multiple significant reductions from baseline in metabolic outcomes. Cook et al reported a significant association between vegetable intake, decreased visceral adipose tissue, and improved hepatic fat fractions. Both studies found that consumption of plant based foods may be associated with decreased insulin resistance in overweight or obese children. The benefits of consuming plant based foods appear to be substantial and low risk in this population as long as proper education and monitoring to ensure a balanced diet is carried out. However, the significant mean increase in HgbA1C levels noted by Macknin et al are worrisome and warrant further investigation. The lack of longitudinal studies and RCT’s examining the longer-term
effects of a PBD on metabolic risk in overweight or obese children point to the need for further research in this field. In future studies, efforts should be made to control for significant confounding variables including physical activity, past medical history, and medication use.
References


<table>
<thead>
<tr>
<th>Design</th>
<th>Outcomes of Interest</th>
<th>Downgrade Criteria</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macknin et al&lt;sup&gt;11&lt;/sup&gt;</td>
<td>BMI, fasting glucose, fasting insulin, mid-arm circumference, waist circumference, BP, MPO, hsCRP, IL-6, AST, ALT, TC, triglycerides, HDL-C, LDL-C, HgbA1C</td>
<td>Serious&lt;sup&gt;a&lt;/sup&gt; Not Serious Not Serious Not Serious Unlikely None</td>
<td>Moderate</td>
</tr>
<tr>
<td>Cook et al&lt;sup&gt;12&lt;/sup&gt;</td>
<td>BMI, fasting glucose, fasting insulin, subcutaneous adipose tissue, visceral adipose tissue, hepatic fat fraction, homeostasis assessment model of insulin resistance, insulin sensitivity, acute insulin response, disposition index</td>
<td>Serious&lt;sup&gt;b&lt;/sup&gt; Not Serious Not Serious Not Serious Unlikely None</td>
<td>Very Low</td>
</tr>
</tbody>
</table>

<sup>a</sup> Lack of control group, possibility of confounders (past medical history, medication use, recall bias)

<sup>b</sup> Possibility of confounders in studies analyzed (physical activity level, recall bias)
### Table II. Summary of Findings: Macknin et al[^11]

<table>
<thead>
<tr>
<th>Outcomes in the PBD group</th>
<th>Macknin et al (2015)(^{11})</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dietary Intake</strong></td>
<td></td>
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<tr>
<td>Energy (kcal)</td>
<td>1686.32</td>
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<tr>
<td>Total fat (g)</td>
<td>65.72</td>
</tr>
<tr>
<td>Total carbohydrate (g)</td>
<td>217.35</td>
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<tr>
<td>Total protein (g)</td>
<td>63.61</td>
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<tr>
<td>Animal protein (g)</td>
<td>42.32</td>
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<tr>
<td>Cholesterol (mg)</td>
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<td>Omega-3 fatty acids (g)</td>
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<td>Total dietary fiber (g)</td>
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<tr>
<td>Vitamin D (ug)</td>
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<td>Vitamin B12 (ug)</td>
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<td>Calcium (mg)</td>
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<td>Iron (mg)</td>
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<tr>
<td>Sodium (mg)</td>
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<table>
<thead>
<tr>
<th><strong>Clinical Outcomes</strong></th>
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<tbody>
<tr>
<td>BMI (z-score)</td>
<td>1.90</td>
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<tr>
<td>Weight (kg)</td>
<td>79.62</td>
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<tr>
<td>Mid-arm circumference (cm)</td>
<td>33.30</td>
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<tr>
<td>SBP (mmHg)</td>
<td>116.25</td>
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<td>Insulin (uU/mL)</td>
<td>17.33</td>
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<tr>
<td>HOMA-IR</td>
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<tr>
<td>Cholesterol (mg/dL)</td>
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<tr>
<td>Triglycerides (mg/dL)</td>
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<tr>
<td>HDL-C (mg/dL)</td>
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<td>LDL-C (mg/dL)</td>
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<td>Glucose (mg/dL)</td>
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<td>IL-6 (pg/mL)</td>
<td>1.72</td>
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<tr>
<td>MPO (pmol/L)</td>
<td>287.54</td>
</tr>
<tr>
<td>HgbA1C</td>
<td>5.77</td>
</tr>
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</table>
### Table III. Summary of Findings: Cook et al\textsuperscript{12}

<table>
<thead>
<tr>
<th>All Vegetables</th>
<th>Quartiles of Intake</th>
<th>P value (between quartiles)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1</td>
<td>Q2</td>
</tr>
<tr>
<td>Servings (n)</td>
<td>0.1±0.1 (43)</td>
<td>0.5±0.1 (44)</td>
</tr>
<tr>
<td>Hepatic fat fraction (%)</td>
<td>10.9±8.6</td>
<td>9.5±8.9</td>
</tr>
<tr>
<td>Acute insulin response (μU/mL×10 min)</td>
<td>1,810.6±1,001.0</td>
<td>1,104.2±1,061.7</td>
</tr>
<tr>
<td>Nonstarchy vegetables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Servings (n)</td>
<td>0.1±0.1 (43)</td>
<td>0.5±0.1 (44)</td>
</tr>
<tr>
<td>Hepatic fat fraction (%)</td>
<td>10.0±8.5</td>
<td>10.0±8.3</td>
</tr>
<tr>
<td>Acute insulin response (μU/mL×10 min)</td>
<td>1,874.1±1,001.9</td>
<td>1,114.6±1,044.7</td>
</tr>
<tr>
<td>Nutrient-rich vegetables</td>
<td>Nonconsumers</td>
<td>Consumers</td>
</tr>
<tr>
<td>Servings (n)</td>
<td>0.0±0.00 (68)</td>
<td>0.3±0.4 (107)</td>
</tr>
<tr>
<td>Visceral adipose tissue volume (L)</td>
<td>2.3±0.9</td>
<td>1.9±0.7</td>
</tr>
<tr>
<td>Acute insulin response (μU/mL×10 min)</td>
<td>1,588.0±854.0</td>
<td>1,191.0±685.6</td>
</tr>
<tr>
<td>Insulin sensitivity (×10^-4/min/μU/mL)</td>
<td>1.6±1.6</td>
<td>2.1±1.3</td>
</tr>
</tbody>
</table>