FINAL PROJECT REPORT

Project Title: Health role of pear for Metabolic Syndrome

PI: Bahram H. Arjmandi, PhD, RD
Organization: Department of Nutrition, Food and Exercise Sciences, Florida State University
Telephone: (850) 645-1517
Email: barjmandi@fsu.edu
Address: 412 Sandels Building, 120 Convocation Way, Tallahassee, Florida 32306-1493

Co-PI: Sarah A. Johnson, PhD, RDN
Organization: Department of Food Science and Human Nutrition, Colorado State University
Telephone: (970) 491-3807
Email: sarah.johnson@colostate.edu
Address: 206 Gifford Building, 502 W. Lake St., Fort Collins, Colorado 80523-1571

Cooperators: Pear Bureau Northwest

Total Project Request: **Year 1:** $32,185 **Year 2:** $29,871 **Year 3:** $18,000

Other funding sources

Agency Name: Pear Bureau Northwest
Amount awarded: Year 1: $32,185 **Year 2**: $29,871 **Year 3:** $N/A
Notes: Pear Bureau Northwest matched the amount funded by the Pear Marketing Order 927 to bring the total funded amount to $64,370 for Year 1 and $59,742 for Year 2.

Total Project Funding: $80,056

Budget History

Item	2014	2015	2016
Salaries	$16,457.50	$16,951	$0
Benefits	$2,688	$2,853	$0
Wages	$0	$0	$0
Benefits	$0	$0	$0
Equipment	$0	$0	$0
Supplies	$12,539.50	$9,067	$18,000
Travel	$0	$0	$0
Miscellaneous	$500	$1,000	$0
Plot Fees	$0	$0	$0
Total	$32,185	$29,871	$18,000

A. OBJECTIVES

The ***central hypothesis*** of this study was that daily consumption of 2 pears (medium sized Green Bartlett and/or Green Anjou pears weighing ~166 g each) for twelve weeks would improve blood pressure, lipid profiles, glycemic control and insulin resistance, inflammatory and oxidative status in men and women with MetS. Because pears are high in pectin, a soluble and fermentable dietary fiber, we propose two ***ancillary hypotheses*** as follows: **1)** regular intake of pears will promote gastrointestinal health (GI); and **2)** will improve measures of body composition. The hypotheses of the study were tested in a randomized, crossover design study using 2 pears or 50 g isocaloric control drink powder with 50 men and women between the ages of 45 and 65 years with three of the five features of MetS using the following four ***specific aims***:

Specific Aim 1: To investigate the extent to which daily pear consumption reduces blood pressure and improves lipid profiles by measuring total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), apolipoprotein A1 and apolipoprotein B100 levels will be measured. Atherogenic risk ratios (TC/HDL-C, LDL-C/HDL-C, HDL-C/LDL-C) will also be assessed.

***Specific Aim 2*:** To determine the degree to which daily pear consumption will improve biochemical markers of **a)** inflammation [C-reactive protein (CRP), leptin, and adiponectin]; **b)** antioxidant defense [total antioxidant capacity (TAC)]; **c)** oxidative stress [oxidized low-density lipoprotein (LDL) and 8-hydroxy-2'-deoxyguanosine (8-OHdG)]; and **d)** insulin sensitivity [(fasting glucose, insulin, the homeostatic model assessment-insulin resistance (HOMA-IR)].

Specific Aim 3: To investigate the ability of pear consumption to improve GI health using a validated Seven-Day Bowel Movement Questionnaire and serum levels of short-chain fatty acids.

***Specific Aim 4*:** To examine whether pear consumption has positive effects on body weight and composition including lean body mass (LBM), fat mass (FM) and percent body fat (%BF) using dual-energy x-ray absorptiometry (DXA).

B. SIGNIFICANT FINDINGS

- Subject recruitment and overall subject retention was excellent (**Fig. 1**) with only 7 participants dropping from the study (14% attrition).
- Systolic blood pressure was reduced by 3.7% ($p = 0.01$) and pulse pressure (difference between systolic and diastolic blood pressure) was significantly ($p < 0.05$) reduced by 7.4% at 12 weeks in the Pear group but not in the Control group. There were no differences between groups so a treatment effect cannot be confirmed; however, this is suggestive of blood pressure reducing effects of pears.
- Triglyceride levels were significantly ($p < 0.05$) reduced by 3.5% and HDL-C levels were ($p < 0.1$) increased by 6.8% in the Pear group but not in the Control group. There were no significant differences between groups so a treatment effect cannot be confirmed; however, this is suggestive of improvements in lipid parameters due to pear consumption.
- Total cholesterol and LDL-C were increased at 6 and 12 weeks in both groups. The changes over time were in both groups so cannot be attributed to pears, but rather a time effect.
- Waist circumference was significantly ($p < 0.05$) reduced by 0.56% at 12 weeks and waist-to-hip ratio was significantly ($p < 0.05$) reduced by 0.54% at 6 and 12 weeks, respectively. There were no differences between groups so a treatment effect cannot be confirmed; however, a significant increase in waist circumference was noted at 6 weeks in the Control group and was sustained at 12 weeks, while percent android (abdominal) fat was increased at 6 and 12 weeks compared to baseline in the control group. Android-to-gynoid ratio (abdominal fat to hip fat) was increased in the control group at 12 weeks. Additionally, leptin was significantly ($p < 0.05$) reduced at 12 weeks by 4.3% and levels were significantly ($p < 0.05$) lower than the Control group. *This suggests a possible shift in fat distribution favoring less leptin production due to a reduction in leptin resistance*. Importantly, the control drink

(addition of calories in the form of carbohydrates) had moderate but detrimental effects on body composition while the pear intervention improved parameters of body composition. Although a treatment effect was not noted (with the exception of leptin), these results suggest that pear consumption may have favorable effects on body composition.

C. OUTLINE OF METHODS

A total of 50 men and women between the ages of 45 and 65 years with three of the five features of MetS were included in the study. After a two-week run-in phase, eligible men and women were randomly assigned to receive one of two treatments daily for twelve weeks: 1) Two medium-sized pears or 2) 50 g isocaloric maltodextrin-based pear-flavored control drink powder. After an initial ***telephone screening***, all participants were requested to report to the study site for their first visit. On the **first visit (screening)**, potential subjects were provided with verbal and written explanation of the project and individuals were then asked to sign an informed consent form, followed by measuring waist circumference, resting brachial blood pressure, fasting serum triglycerides, HDL-C, and glucose levels using the Cholestech LDX® System (Waltham, MA) to confirm MetS. Baseline assessments were performed for medical history, medication use, dietary intake, and physical activity. Volunteers who met the study criteria were scheduled for their second visit two weeks later (actual baseline data collection) and randomly assigned to their treatment group. They were given a three-day food record to take home and bring back on the second visit. During the **second (baseline) visit (2-weeks)** this visit between the hours of 7-10 A.M., urine was collected, blood pressure was measured followed by blood draw. Subjects' anthropometrics including height, weight, and waist and hip circumferences were measured. Participants were asked to complete Physical Activity and Bowel Movement Questionnaires. Next participants underwent a DXA scan for body composition measurements. They were then provided with their assigned treatment and will receive standard instructions on how to fill out daily diaries for their treatment, and for food records. Urine collection, blood pressure, blood draw, and anthropometric, body composition, diet, physical activity, and bowel movement assessments were repeated at **6- (third visit) and 12-week (final visit)** intervals. Participants were provided with light breakfast items before leaving the clinical research facility. After completing the assigned 12-week intervention, subjects underwent a 4-week washout period before crossing over to the other intervention and all respective procedures were followed at baseline, 6- and 12-week visits.

Study Procedures	**Screening**	**Baseline**	**6 Weeks**	**12 Weeks**
Informed Consent	X			
Medical History	X			
Three-Day Food Record	X	X	X	
Physical Activity Questionnaire		X	X	X
7-Day Bowel Movement Questionnaire		X	X	X
Anthropometrics	X	X	X	X
DXA		X		X
Blood Draws	X	X	X	X
Urine Collection		X	X	X
Blood Pressure	X	X	X	X
Assess Compliance	Ongoing throughout the study.			

Table 1. Study Procedures.

<u>Data Analyses and Management:</u>

An initial sample size of 50 subjects, with a projected attrition rate of 20% was projected to produce a sample size of approximately 40 participants in a crossover design with greater than 80% power of more than 0.85 at an $\alpha = 0.05$ to detect a significant difference ($p < 0.05$). SAS v9.4 (SAS Institute Inc., Cary, NC) was used for all statistical analyses. A linear regression analysis was used to evaluate the difference between the groups as well as the difference between different time points taking into account the clustering effect of each subject. If the outcome data was not normally distributed, log conversion was performed. A *p*-value of 0.05 was used to evaluate statistical significance.

D. RESULTS AND DISCUSSION

Results:

Subject Enrollment and Attrition

As mentioned in the Significant Findings section, subject recruitment and overall subject retention was excellent with only 7 participants dropping from the study (14% attrition) (**Fig. 1**). Reasons for dropping from the study included personal reasons such as lack of time or moving, not wanting to take the placebo powder, and not wanting to give blood. Tolerance to daily pear consumption was generally reported as good; however, there were reports of taste fatigue towards the end of the 12-week pear interventions.

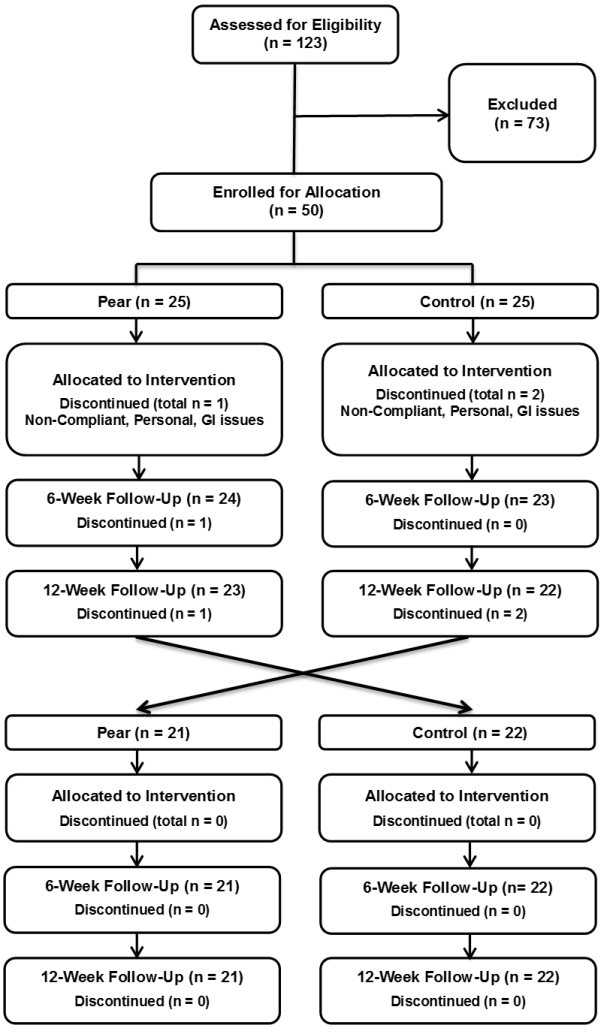

Figure 1. Flowchart of Enrollment

Anthropometrics, Physical Activity Expenditure, and Energy Intake

No differences were observed over time or between groups for weight, BMI, or energy intake. Self-reported physical activity expenditure increased (172 Kcal) from baseline to 6 weeks in the Control group but not in the Pear group. Waist circumference and waist-to-hip ratio were improved at 12 weeks and at 6 and 12 weeks, respectively. There were no differences between groups so a treatment effect cannot be confirmed; however, a significant increase in waist circumference was noted at 6 weeks in the control group and was sustained at 12 weeks.

Table 1. Anthropometric measurements, physical activity expenditure, and energy intake.

	Pear			Control		
Measures	**Baseline**	**6 weeks**	**12 weeks**	**Baseline**	**6 weeks**	**12 weeks**
Weight, kg	92 ± 2	92 ± 2	92 ± 3	92 ± 2	92 ± 2	92 ± 3
BMI, kg/m²	33 ± 1	33 ± 1	33 ± 1	33 ± 1	33 ± 1	34 ± 1
WC, cm	108.1 ± 1.9	107.8 ± 1.9	107.5 ± 2.0*	107.9 ± 2.0	108.4 ± 1.9*	108.1 ± 1.9
Waist/Hip	0.930	0.926$^{\pm}$	0.925$^{\pm}$	0.936	0.923	0.932
PA, Kcal	3256 ± 94	3345 ± 114	3439 ± 150	3222.5 ± 100	3394 ± 124*	3356 ± 135
EI, Kcal	1777 ± 128	1984 ± 113	2012 ± 146	2033 ± 124	1960 ± 165	2167 ± 164

Values reported as mean ± SEM. *Significantly ($p < 0.05$) different compared to baseline. $^{\pm}$Significantly ($p < 0.05$) different compared to Control. **Abbreviations:** BMI, body mass index; EI, energy intake; PA, physical activity; WC, waist circumference.

Blood Pressure

Blood pressure parameters are presented in **Table 2**. Systolic blood pressure (-5 mmHg) and pulse pressure (-4) were significantly lower at 12 weeks compared to baseline in the Pear group while no changes were noted in the control group. Heart rate was significantly greater (+2 beats/min) at 12 weeks compared to baseline in the Pear group but not in the Control group. No significant differences were noted between groups at any time point and therefore a treatment effect cannot be confirmed; however, this is suggestive of blood pressure lowering effects due to pear consumption.

Table 2. Blood pressure parameters.

	Pear			Control		
Measures	**Baseline**	**6 weeks**	**12 weeks**	**Baseline**	**6 weeks**	**12 weeks**
SBP, mmHg	135 ± 2.0	133 ± 2	130 ± 2†	133 ± 2	134 ± 2	131 ± 2
DBP, mmHg	80 ± 1	80 ± 1	80 ± 1	81 ± 1	81 ± 1	80 ± 1
PP	54 ± 1	54 ± 1	50 ± 1*	52 ± 2	53 ± 2	51 ± 2
MAP, mmHg	98 ± 1	98 ± 1	97 ± 1	98 ± 1	98 ± 1	98 ± 1
HR, beats/min	69 ± 1	70 ± 1	71 ± 1*	71 ± 2	71 ± 1	71 ± 2

Values are mean ± SEM. *Significantly different compared to baseline. **Abbreviations:** SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; MAP, mean arterial pressure; PP, pulse pressure.

Blood and Urinary Biomarkers

Blood and urinary biomarker results are presented in **Table 3**. Triglyceride levels were reduced (-5.11 mg/dL) and HDL-C tended to increase (3.34 mg/dL) in the Pear group but not in the Control group. There were no differences between groups so a treatment effect cannot be confirmed; however, this is suggestive of improvements in lipid parameters due to pear consumption. Total cholesterol and LDL-C were increased at 6 and 12 weeks in both groups. The changes over time were in both groups so cannot be attributed to pears, but rather a time effect. Leptin was reduced at 12 weeks and levels were significantly lower than the control group at this time point suggesting a treatment effect due to pear consumption.

Table 3. Blood and urinary biomarkers.

	Pear			Control		
Measures	**Baseline**	**6 weeks**	**12 weeks**	**Baseline**	**6 weeks**	**12 weeks**
Fasting Glucose, mg/dL	107.58 ± 2.17	109.52 ± 2.44	109.91 ± 2.50	106.40 ± 2.25	108.63 ± 2.45	106.98 ± 2.23
Insulin (pmol/L)	131.96 (117.58, 177.66)	131.96 (120.65, 172.33)	128.49 (123.13, 173.52)	125.01 (119.39, 169.72)	125.01 (120.80, 195.77)	118.07 (117.76, 203.01)
HOMA-IR	2.51 (2.26, 3.31)	2.59 (2.32, 3.23)	2.46 (2.36, 3.27)	2.38 (2.25, 3.29)	2.39 (2.32, 3.61)	2.30 (2.29, 3.68)
HOMA-B%	131.79 ± 7.08	129.86 ± 7.15	130.54 ± 7.28	135.50 ± 6.54	134.21 ± 8.44	140.21 ± 9.73
QUICKI	2.78 ± 0.26	2.78 ± 0.26	2.78 ± 0.26	2.78 ± 0.26	2.78 ± 0.26	2.78 ± 0.26
TG, mg/dL	145.28 ± 12.41	156.44 ± 12.0	140.17 ± 12.19*	143.07 ± 9.65	145.05 ± 10.42	149.56 ± 11.07
TC, mg/dL	195.61 ± 5.91$^{\#}$	201.21 ± 6.73*$^{\#}$	200.02 ± 5.97	202.05 ± 5.66	208.72 ± 6.58*	203.81 ± 5.96
LDL-C, mg/dL	94.14 ± 4.99	99.07 ± 5.34*	100.69 ± 4.92*	95.53 ± 4.62	103.67 ± 5.07*	103.07 ± 4.69*
HDL-C, mg/dL	49.16 ± 1.46	49.14 ± 1.63	52.50 ± 3.41†	50.26 ± 1.76	51.21 ± 1.82	50.19 ± 1.61
Apo B	101.98 ± 3.58	103.28 ± 3.97	100.61 ± 3.56	103.86 ± 3.54	106.74 ±3.99	101.35 ± 3.73
Apo A	2.30 ± 0.09	2.37 ± 0.10	2.38 ± 0.09	2.35 ± 0.12	2.33 ± 0.07	2.45 ± 0.10
Leptin	52.72 (46.78, 66.40)	46.67 (36.74, 108.47)	50.45 (40.31, 60.99)$^{\dagger\pm}$	53.61 (43.84, 60.37)	52.89 (48.80, 68.0)	53.04 (48.32, 66.77)
Adiponectin	5.90 (5.96, 7.11)	5.82 (5.77, 6.95)	6.12 (5.69, 7.08)	6.06 (5.75, 6.87)	5.83 (5.62, 7.16)	6.06 (5.58, 6.93)

CRP	4.08 (4.01, 7.84)	3.73 (3.78, 6.18)	4.13 (3.67, 6.57)	3.78 (4.03, 6.77)	4.11 (4.07, 6.84)	3.68 (3.79, 6.29)
8-OHdG	1.50 ± 0.06	1.56 ± 0.05	1.50 ± 0.07	1.53 ± 0.050	1.59 ± 0.054	1.47 ± 0.05
TAS	1.40 (1.37, 1.48)	1.41 (1.36, 1.46)	1.38 (1.36, 1.43)	1.38 (1.37, 1.48)	1.42 (1.38, 1.49)	1.38 (1.38, 1.48)

Values are mean ± SEM, or median with 95% CI in parentheses (all such values). These values are presented because of nonnormally distributed model residuals; log-transformed values are analyzed in model. *Significantly ($p < 0.05$) different compared to baseline. †Tends to be significantly ($p = 0.069$) different at 12-week between groups. ‡Significantly ($p < 0.05$) different compared to Control. **Abbreviations:** HOMA-IR, Homeostatic model assessment of insulin resistance; HOMA-B%, homeostasis model assessment of beta-cell function; QUICKI, quantitative insulin-sensitivity check indexes; TG, triglycerides; TC, total cholesterol; LDL-C, low-density lipoprotein-cholesterol, HDL-C, high-density lipoprotein-cholesterol; Apo B, apolipoprotein B100; Apo A, apolipoprotein A; CRP, C-reactive protein; 8-OHdG, 8-hydroxy- 2'-deoxyguanosine; TAS, total antioxidant status.

Body Composition

Body composition results are presented in **Table 4**. Percent android (abdominal) fat was increased (+0.6%) at 6 and 12 weeks compared to baseline in the Control group. Android-to-gynoid ratio (abdominal fat to hip fat) was increased (0.22) in the Control group at 12 weeks. There were no significant changes noted in any time point for the Pear group.

Table 4. Body composition (DXA).

	Pear			Control		
Measures	**Baseline**	**6 weeks**	**12 weeks**	**Baseline**	**6 weeks**	**12 weeks**
Fat Mass (%)	43.5 ± 1.0	43.4 ± 1.0	reanalyzing	43.3 ± 1.0	43.7 ± 1.0	43.5 ± 1.0
Lean Mass (kg)	52.3 ± 1.5	52.4 ± 1.5	49.1 ± 2.2[b]	52.2 ± 1.5	51.3 ± 1.9	51.6 ± 1.9
Fat Mass (kg)	108.6 ± 12.8	108.2 ± 13.0	107.6 ± 13.5	107.5 ± 12.2	108.0 ± 11.3	107.4 ± 11.5
Android Fat (g)	7061.2 ± 428.0	7086.6 ± 421.3	7076.6 ± 431.6	7174.4 ± 389.6	7165.0 ± 435.0	7061.9 ± 434.5
Gynoid Fat (g)	12318.1 ± 693.6	12137.7 ± 706.9	15111.6 ± 615.1	13008.8 ± 603.2	13112.0 ± 571.3	13570.6 ± 590.8
Android Fat (%)	50.8 ± 0.9	50.7 ± 1.0	50.6 ± 1.0	50.2 ± 1.0	50.8 ± 1.0*	50.8 ± 1.0*
Gynoid Fat (%)	42.6 ± 1.3	42.5 ± 1.2	42.8 ± 1.3	42.8 ± 1.3	42.9 ± 1.3	42.8 ± 1.4
Android/Gynoid Ratio	1.22 ± 0.03	1.23 ± 0.03	1.21 ± 0.01	1.20 ± 0.03	1.89 ± 0.67	1.22 ± 0.03*

Values are mean ± SEM. *Significantly ($p < 0.05$) different compared to baseline.

Gastrointestinal Health

7-day gastrointestinal health questionnaire results are presented in **Table 5**. No improvements were noted in any of the parameters over the course of the treatment period. Pain was reported to increase at 12 weeks of treatment. There were significant differences between groups at baseline for pain and

consistency. Importantly, there was poor subject compliance with filling out and returning these questionnaires which likely the reason for these findings as there was missing data at numerous time points.

Table 5. Gastrointestinal health questionnaire.

			Pear			Control
Measures	**Baseline**	**6 weeks**	**12 weeks**	**Baseline**	**6 weeks**	**12 weeks**
Frequency, per day	1.55 ± 0.11	1.49 ± 0.12	1.39 ± 0.11	1.52 ± 0.11	1.53 ± 0.11	1.89 ± 0.45
Quantity, cups	1.54 ± 0.13	1.57 ± 0.16	1.44 ± 0.14	1.44 ± 0.12	1.50 ± 0.15	1.23 ± 0.27
Consistency	3.66 ± 0.15$^{\pm}$	3.45 ± 0.16	3.55 ± 0.18	3.29 ± 0.16^{a}	3.33 ± 0.16	3.25 ± 0.35
Straining	2.29 ± 0.18	2.53 ± 0.20	2.58 ± 0.24	2.43 ± 0.19	2.59 ± 0.17	2.47 ± 0.50
Pain	1.66 ± 0.12$^{\pm}$	1.86 ± 0.17	2.10 ± 0.21*	2.01 ± 0.17	2.09 ± 0.17	1.82 ± 0.42
Feeling of constipation	1.98 ± 0.19	2.07 ± 0.20	2.28 ± 0.24	2.10 ± 0.20	2.08 ± 0.16	2.0 ± 0.37

Values are mean ± SEM. *Significantly ($p < 0.05$) different compared to baseline. $^{\pm}$Significantly ($p < 0.05$) different compared to Control.

Discussion:

This is the first randomized controlled clinical trial conducted in the United States using fresh pears as an intervention. As such, this study is novel in that it utilized a fresh fruit rather than a dried fruit or powder, or a juice. An additional novel aspect of this study is that we utilized a crossover (within subject) design such that subjects served as their own controls.

Overall, there was excellent subject retention throughout the course of the study (7 out of 50 subjects dropped total) as well a high subject compliance (self-reported) with the treatments. Taste fatigue due to fresh pear consumption was commonly reported towards the end of the 12-week intervention. This is common in clinical studies involving daily treatment consumption (in the form of food) for an extended period of time. There were no reports of inability to tolerate the treatments. This suggests that daily fresh pear consumption if feasible for middle-age and older adults.

The major findings of this study suggest that fresh pear consumption promotes modest improvements in the cardiometabolic health of middle-aged and older adults with MetS. There were improvements in certain parameters over the course of the 12-week study period, namely systolic blood pressure, pulse pressure, triglycerides, HDL-C, leptin, waist circumference, and waist-to-hip ratio in the Pear group. However, only a between group (treatment effect) was noted for leptin. Nonetheless, improvements in these parameters were not observed in the Control group. As such, this suggests that fresh pear consumption may improve parameters of cardiometabolic health in middle-age and older adults with MetS. Additionally, leptin is a hormone produced by adipose tissue (fat) and individuals with greater levels of adipose tissue often have higher levels of leptin due to leptin resistance which leads to a reduced ability to control hunger and regulate body weight. Leptin plays an important role in satiety and hunger regulation and has pro-inflammatory effects. A reduction in leptin may be partly due to a shift in the distribution of or in the amount of adipose tissue. Additionally, this may indicate

that these individuals had improved satiety due to pear consumption as a reduction in leptin is suggestive of less leptin resistance. This cannot be confirmed at this time as satiety was not assessed in our study. However, there were no changes in self-reported energy intake throughout the course of the study.

It is important to note that MetS is a cluster of cardiometabolic risk factors. In order to be diagnosed with MetS, one needs to have 3 out of the 5 criteria for MetS (high blood pressure, high blood glucose or triglyceride levels, low HDL-C levels, or a high waist circumference. Hence, not all of our subjects had the same cardiometabolic risk factors. As such, this may be a factor contributing to the lack of a larger improvement and therefore a treatment effect. In the future, it may be of benefit to design studies using a population with more uniform metabolic syndrome or cardiometabolic risk factors (e.g. high systolic blood pressure or hyperlipidemia) to observe significant between group differences in outcome parameters.

With regard to the intervention, due to seasonal changes in pear production, we used a combination of green Anjou and green Bartlett. Because the study duration (data collection from the first subject to the last subject) occurred over the period of approximately 2 years and 4 months, there was variation in the types and quantities of each type of pear that each subject consumed. Due to the nature of the intervention (fresh pears), this variation is not something that can be controlled for a large study. It is known that the nutrient and bioactive compound composition of fresh produce can vary for multiple reasons. Also, our intervention utilized green pears rather than red pears. It is possible that red pears contain different types and quantities of bioactive compounds that may exert different or greater health effects than green pears. We are unable to determine whether the above-mentioned factors contributed to our findings; however, these factors should be considered when designing future clinical studies.

Subject compliance was reported to be good throughout the duration of the study, although there were some instances of subjects reporting issues with ripening of pears despite education about ripening throughout the course of the study. Compliance was self-reported as is done in many clinical trials, and hence there is always the possibility that subject compliance was not as good as what was reported. This a limitation of our study but is not something that can be controlled for at this time. It would be of benefit for future studies to investigate biomarkers of pear intake, e.g. a metabolite signature using metabolomics analysis that could be used to monitor intake and compliance in clinical studies. In addition, while subject compliance was very good throughout the course of the study, subjects had poor compliance with completing and returning their gastrointestinal health questionnaires. Future studies should evaluate objective measures of gastrointestinal health such as the gut microbiome.

Overall, the results of this study suggest that daily fresh pear consumption promotes cardiometabolic health in middle-aged and older men and women with MetS. Although the effects could be considered modest due to the lack of a between group (treatment effect) for the majority of the improvements observed, the findings are consistent with previous research conducted with pears and should be viewed as positive. The addition of two fresh pears into the diet was well-tolerated, promoted high compliance, and led to improvements in cardiometabolic health parameters over time that were not observed in the control group. It is likely that the addition of fresh pears in combination with other health-promoting foods to the diet or in the context of a health dietary pattern (e.g. DASH or Mediterranean diet) would contribute to significant improvements in cardiometabolic health in middle-aged and older individuals. As such, our findings can be used to promote fresh pear consumption in middle-aged and older adults with cardiometabolic risk factors. Promotion of the health benefits of fresh pear consumption on cardiometabolic health in this population could promote increased pear sales and consumption and therefore a greater demand for fresh pears.

E. EXECUTIVE SUMMARY

Metabolic syndrome (MetS) is a cluster of major cardiovascular risk factors including abdominal obesity, elevated blood pressure, atherogenic dyslipidemia and insulin resistance, and a pro-inflammatory and pro-thrombotic state, and is highly associated with the development of chronic diseases such as cardiovascular disease and type II diabetes. The primary treatment goals for individuals with MetS is to improve modifiable underlying risk factors such as body weight, physical activity, and diet through lifestyle changes. Pears (*Pyrus communis*) are a commonly consumed fruit and are an excellent source of soluble and insoluble dietary fiber, a good source of vitamin C and contains potassium and vitamin K, and bioactive compounds including flavonoids (e.g. anthocyanins and flavanols) and phenolic acids (e.g. gallic acid and chlorogenic acid). Although there is a paucity of clinical research that has investigated the impact of pear consumption on human health, previous research with pears supports their potential as a functional food for promoting overall health, especially with respect to the characteristics of MetS. The central hypothesis of this study was that daily consumption of 2 fresh pears for twelve weeks would improve blood pressure, lipid profiles, glycemic control and insulin resistance, inflammatory and oxidative status, body composition, and subjective measures of gastrointestinal health in middle-aged and older men and women with MetS. Fifty men and women aged 45 to 65 years with three of the five features of MetS were randomly assigned to receive either 2 medium-sized fresh pears (Pear) or 50 g pear-flavored placebo drink mix (Control) per day for 12 weeks. At the end of the 12-week period, subjects underwent a 4-week washout period and then crossed over to the other group. At baseline, 6-week, and 12-week visits, subjects underwent assessments of anthropometrics and body composition, brachial blood pressure, gastrointestinal health, food and nutrient intake, and physical activity, and blood and urine were collected. Overall, subject recruitment and overall subject retention was excellent with only 7 participants dropping from the study (14% attrition). Tolerance and compliance to treatments were reported to be very good. Laboratory and statistical analyses were performed for the 43 subjects who completed the entire study. Systolic blood pressure tended ($p < 0.1$) to be reduced and pulse pressure (difference between systolic and diastolic blood pressure) was significantly ($p < 0.05$) reduced at 12 weeks in the Pear group but not in the Control group. Triglyceride levels were significantly ($p < 0.05$) reduced and HDL-C levels tended ($p < 0.1$) to be increased in the Pear group but not in the Control group. Waist circumference was significantly ($p < 0.05$) reduced at 12 weeks and waist-to-hip ratio was reduced at 6 and 12 weeks, respectively in the Pear group while a significantly ($p < 0.05$) increase in waist circumference was noted at 6 weeks in the Control group and was sustained at 12 weeks. Percent android (abdominal) fat was significantly ($p < 0.05$) increased at 6 and 12 weeks compared to baseline and android-to-gynoid ratio (abdominal fat to hip fat) was significantly ($p < 0.05$) increased in the Control group at 12 weeks compared to baseline while no changes were noted in the Pear group. Additionally, leptin was significantly ($p < 0.05$) reduced at 12 weeks and levels were significantly ($p < 0.05$) lower than the Control group. The major findings of this study suggest that fresh pear consumption promotes modest improvements in the cardiometabolic health of middle-aged and older adults with MetS. There were improvements in certain parameters over the course of the 12-week study period, namely systolic blood pressure, pulse pressure, triglycerides, HDL-C, leptin, waist circumference, and waist-to-hip ratio in the Pear group. However, only a between group (treatment effect) was noted for leptin. Nonetheless, improvements in these parameters were not observed in the Control group. As such, this suggests that fresh pear consumption may improve parameters of cardiometabolic health in middle-age and older adults with MetS. Future studies may benefit from evaluating a population with more uniform cardiometabolic risk factors to observe significant between group differences in outcome parameters. Additionally, future studies may wish to consider the types of pears used (red vs. green) and seasonality of different pear types. Further, establishing biomarkers of pear consumption using omics methodologies (e.g. metabolomics analyses) would be of benefit in conducting and evaluating clinical and epidemiologic human studies involving fresh pear consumption. Our next step is to disseminate our findings through conference presentations and publications.