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Daily Pork Consumption as a Part of the Dietary Approaches to Stop Hypertension Diet Influences Body Composition and Preserves Muscle Mass in Older Adults Consuming Controlled Intakes

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABBREVIATIONS

ADL’s	Activities of Daily Living
AFM	Absolute Fat Mass
BMI	Body Mass Index
BP	Blood Pressure
Cm	Centimeters
DASH	Dietary Approaches to Stop Hypertension
DBP	Diastolic Blood Pressure
FM	Fat Mass
FFM	Free Fat Mass
FNIH	Foundation for the National Institutes of Health
G	Grams
g/kg/day	Grams per kilogram of body weight per a day
Kcal	Kilocalories
Kg	Kilograms
kg/ m^2	Kilograms per meter squared
LBM	Lean Body Mass
L/F	Low fat
L/S	Low Sodium
Mg	Milligrams
mmHg	Millimeter of Mercury
n	Number of Participants
oz	Ounces

RDA	Recommended Dietary Allowance
REE	Resting Energy Expenditure
REE-kg	Resting Energy Expenditure per kilogram body weight
SBP	Systolic Blood Pressure
SD	South Dakota
SDSU	South Dakota State University
SMM	Skeletal Muscle Mass
TBW	Total Body Water
U.S	United States
USDA	United States Department of Agriculture
Wks	Weeks
WHO	World Health Organization
WW	Whole Wheat
% body fat	Percent Body Fat
°F	Degrees Fahrenheit

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ABSTRACT

DAILY PORK CONSUMPTION AS A PART OF THE DIETARY APPROACHES TO STOP HYPERTENSION DIET INFLUENCES BODY COMPOSITION AND PRESERVES MUSCLE MASS IN OLDER ADULTS CONSUMING CONTROLLED INTAKES

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The purpose of this study was to test the hypothesis that muscular fitness is preserved in older adults who consumed pork daily as a part of the DASH dietary pattern. A controlled feeding pilot study was used to test this. Eight healthy older men and women were randomly assigned to consume either 3 ounces or 6 ounces of pork daily as a part of the DASH diet for a total of 12 weeks. Indicators of muscle mass, strength, and function were assessed at five time points (weeks 0, 3, 6, 9, 12) throughout the 12 weeks. A seven day cyclical menu was developed for the study containing fresh lean pork as the primary protein source at breakfast, lunch, and dinner. These 3 meals along with 2 snacks were provided for participants throughout the study daily. Food items were purchased, prepared, and weighed out to the nearest gram by research staff in a food lab on the SDSU campus.

Changes in body composition and muscular fitness were observed during the 12-wk feeding study regardless of pork intake. Significant time effects were detected for: weight (p=0.000), BMI (p=0.000), waist circumference (p=0.000), hip circumference (p=0.000), % body fat (p=0.000), fat mass (p=0.000), and balance score (p=0.002) such that decrease was observed over the intervention period. Baseline to study end pairwise

comparisons show significant decreases for body weight ($p=0.001$), BMI ($p=0.001$), waist circumference ($p=0.000$), hip circumference ($p=0.001$), % body fat ($p=0.005$), fat mass ($p=0.000$), and right handgrip strength ($p=0.000$). Lean body mass ($p>0.05$) and skeletal muscle mass ($p>0.05$) were well preserved.

The results of this small pilot study indicate that daily consumption of high-quality protein as a part of a healthy dietary pattern positively influences body composition and muscular health in older adults. Results show that fat composition decreases while muscle composition and strength are preserved. These results also suggest that pork can be included in healthy dietary pattern such as that of the DASH diet.

NARRATIVE

CHAPTER 1: LITERATURE REVIEW

Introduction

Aging Population

Population growth in America is estimating remarkable numbers and unusual trends among aging adults. Over the span of a decade from 2000-2010, adults 65 years and older increased by 15.1% compared to the total United States population growth rate of 9.7% (Sinha-Hikim et al., 2013). Significant increases, such as these, will continue to be seen in statistical trends. The current adult population will continue to age driving these growth rates even higher. One estimate notes that 20.3% of the adult population will be 65 years or older by the year 2050. This is about an 8% increase from the year 2000 when adults 65 years or older comprised 12.7% of the total adult population (Tilly & Wiener, 2002). National growth of the older adult population continues, suggesting that research in public health for aging individuals should be of upmost importance.

Engaging this specific population in research merits the continuation and development of methods that benefit quality of life, overall health and wellbeing, and longer lifespans. Coexisting with these beneficiaries are the risks for chronic health conditions that coincide with aging as bodily functions are hindered. Metabolic syndrome, obesity, sarcopenia, hypertension, cardiovascular disease, cancer, and diabetes mellitus are chronic conditions that affect overall health in the older adult population. Individuals with increased risk for one or more of these conditions find themselves in need of ongoing medical attention and care contributing to the economic burden and rising costs of healthcare (Baum & Wolfe, 2015). Many of these conditions coexist together or one may lead to another and so on. Individuals at risk of multiple chronic conditions are rising alongside the increasing number of older adults in the United States. Living with chronic health conditions hinders quality of life and increases the utilization of healthcare services. Furthermore, disability and mortality rates rise among the aging population as a result of impaired quality of life and chronic conditions (Koné Pefoyo et al., 2015).

Economic Burden of Aging

Healthcare services are utilized by older adults more often than that of their younger counterparts. This is a direct result of the onset of aging and chronic conditions that pose increased risk of disability and fatal outcomes. Coinciding with the usage of healthcare, older adults are also more likely to pay higher amounts for healthcare treatment, continued care, or a new diagnosis of a disease and/or condition. As a patient ages, the cost of healthcare for that patient increases. For patients aged over 75 years, the cost of healthcare is three times more than that of the average aged adult (Schueren et al., 2014). More frequent clinic visits, hospital stays, and assisted care are affecting this tripled cost of healthcare.

Aging individuals face the burden of high costs for healthcare that are not covered by private insurance or Medicaid. They pay for these expenses out of pocket for access to long term care options, pharmaceuticals, insurance premiums, and general medical care. A typical 65 year old will pay on average $44,000 towards long term care services, $12,000 for prescription pharmaceuticals, $18,000 for insurance, and $16,000 for medical care (Knickman & Snell, 2002). Economic trends of inflation suggests that these monetary amounts published over 15 years ago have most likely increased alongside the growing population.

Concerns of the aging population will be focused on affordability for receiving appropriate care for their needs and decreasing the burden of healthcare costs for this specific population group. Older adults are more likely to be inflicted with higher expenses for healthcare; however, on average they have significantly lower incomes. Reported data shows that >96% of adults 65 years or older pay for health care expenses out of pocket compared to 89% of adults aged 45-64, and 76% of 18-44 year olds (Choi & DiNitto, 2018). Not only is health care costs a concern for individuals paying out of pocket; but, costs are a concern for national expenses as well adding to economic burden and national debt. National healthcare costs in 2017 were $3.5 trillion U.S. dollars ("NHE Fact Sheet: Historical NHE, 2017," 2019). Developing research highlighting affordable healthcare and preventing chronic diseases that drive the rising costs for aging individuals is a focus area of public health.

Associated Complications of the Aging Population

Sarcopenia

Various chronic conditions that impact older adults were mentioned in the above section. One condition that deserves attention in public health research is sarcopenia. Five to thirteen percent of 60 to 70 year olds experience sarcopenia and in the elderly that are 80 years or older, up to 50% are affected by the condition (von Haehling, Morley, & Anker, 2010). Sarcopenia is characterized by the progressive, age related loss of muscle mass, muscle strength, and decreased physical functions and performance (K. M. Kim et al., 2014). Loss of muscle mass and strength presents risks of associated complications such as: falls, bone fractures, prolonged hospitalizations, loss of mobility, impaired physical functions, and death (Bruyère, Beaudart, Ethgen, Reginster, & Locquet, 2019). Sarcopenia consequences influence overall quality of life and activities of daily living (ADL's).

Sarcopenia etiology is not clearly defined, but several factors could be at fault for the progression of the disease in older adults. Family genetics, inadequate nutrition, hormonal and physiological changes, increased resistance to hormones, inflammation, chronic disease development, and lack of physical activity could all be contributors to loss of muscle mass and strength in the elderly (Akın et al., 2015). Many of these factors contribute to the progression of sarcopenia and are associated with other chronic conditions such as obesity and hypertension.

Obesity

In parallel with the influx of older adults, obesity rates are likewise increasing exponentially affecting the health of aging populations. Obesity rates of 65-74 year olds are 40.2% and 43.5%, respectively for males and females. Individuals aged 75 years or older have 30% average obesity rate (Survey, 2017). Obesity is defined as having a Body Mass Index (BMI) greater than or equal to 30 kg/m² (Wang, McPherson, Marsh, Gortmaker, & Brown, 2011). An individual's height and weight is used to calculate BMI. Although body fat is not included in defining obesity based upon BMI calculations, and overabundance of adipose tissue throughout the body is a contributing factor for defining the condition of obesity (El Ghoch et al., 2018). A higher BMI and/or risk of obesity influences the percentage of individuals who develop chronic health condition as aging occurs (Kritchevsky, 2013). Previously mentioned, individuals at risk of chronic health conditions have a decreased quality of life affecting their health and wellbeing. Former research studies accentuate that a larger BMI, especially those over 30 kg/m^2, are associated with decreased quality of life, increased disabilities and conditions, and higher risk of mortality (J. A. Batsis, Mackenzie, Barre, Lopez-Jimenez, & Bartels, 2014). These characteristics directly impact the growing population of older adults at risk of obesity and chronic health issues.

Sarcopenic Obesity

Sarcopenia and chronic obesity have similar effects on quality of life and health in the aging population. These two conditions can occur simultaneously sharing similar inflammatory response pathways that further exacerbate the outcomes that are associated with each condition alone (John A. Batsis et al., 2013). Sarcopenia was previously discussed as the loss of muscle mass, strength and function. The general public in hearing this definition, would assume that older adults with sarcopenia are frail and underweight. Granted, sarcopenia in its advanced stages may be associated with this (Paddon-Jones, Short, Campbell, Volpi, & Wolfe, 2008).

The prevalence of obese individuals experiencing sarcopenia is greater than those experiencing frailty. Recent statistics estimate that 20% of women and 30% of men have the condition sarcopenic obesity (Garcia-Contreras et al., 2018). Research has determined obesity with sarcopenia is more common than frailty from sarcopenia, suggesting the emphasis that body composition has on sarcopenic obesity. Accumulation of fat mass is hiding the loss of muscle mass in many cases. Obesity research in the older adult population indicates that individuals with higher BMI's are experiencing loss of muscle mass and strength. The loss of muscle mass in older adults is counteracted by fat mass accumulation. Ongoing effects of this results in BMI and bodyweight being stable, in spite of gaining body fat simultaneously with muscle mass loss (Kalyani, Corriere, & Ferrucci, 2014). In turn, this suggests that sarcopenia is characterized not only by loss of muscle mass, strength, and function; but, gaining body fat is a highlighted characteristic as well. Adding this characteristic to the definition proposes the condition of sarcopenic obesity as both concurrently affect the health of aging adults.

Hypertension

Hypertension, otherwise known as persistent high blood pressure (BP), is one of the most prevalent disease conditions worldwide. It can be associated with several conditions of cardiovascular disease such as strokes, coronary artery disease, heart failure, and heart attacks. Hypertension prevalence increases alongside the aging population (Anker et al., 2018). It is estimated that 1 in every 3 adults have hypertension. Furthermore, 1 out of 3 adults are pre-hypertensive and are at risk of developing hypertension ("High Blood Pressure Fact Sheet," 2016). Normal blood pressure levels are less than 120/80 mmHg, while prehypertension is defined as 120/80 mmHg to 139/90 mmHg. Hypertension is then classified as being 140/90 mmHg or above (Han et al., 2014). The top number in these defined figures represents systolic blood pressure (SBP). Systolic pressure identifies the force load that is placed on blood vessel walls when the blood is pumped through the body from the heart contracting. Diastolic blood pressure (DBP) is represented by the bottom number and is the pressure on the vessel walls during relaxation of the heart ("Blood Pressure," 2017). Recent research has demonstrated that SBP rises with age increasing the prevalence of high BP in older adults. An individual can develop hypertension solely based on high SBP values. In contrast, DBP has a tendency to remain the same or slightly decrease after the age of 50 (Chobanian et al., 2003). Blood vessel walls are more likely to become stiff and hard during aging contributing to the SBP rising in relation to increased age (Tin, Beevers, & Lip, 2002). High SBP elevates the amount of pressure placed on the heart to contract and adequate blood flow for the body. Results of consistently high SBP are associated with increased risks of strokes, heart attacks, coronary heart disease, heart failure and mortality (Basile, 2002). These age related effects result in persistent high BP in older adults that are contributing to chronic diseases.

Prevalence of high blood pressure is increased in individuals who experience sarcopenic obesity as they share the characteristic of inflammation and impaired functionality leading to disability (Coelho-Júnior et al., 2018). Inflammation factors are increased during obesity with the accumulation of fat tissues. This increases the risk of cardiovascular diseases such as hypertension (J.-H. Kim, Cho, & Park, 2015). One research study found that a quarter of study participants who had sarcopenic obesity also had diabetes mellitus or hypertension (Kreidieh et al., 2018). This study suggests that hypertension is strongly associated with sarcopenic obesity and is prevalent in the aging population. Another correlation between obesity and hypertension shows that individuals with both conditions have decreased physical function and quality of life (Ucan & Ovayolu, 2010). Weight and blood pressure are directly correlated. Evidence estimates that weight loss of 5.1 kg can lower systolic blood pressure by about 4.5 mmHg (J. L. Appel et al., 2006). Prevalence of obesity and hypertension in older adults are related resulting in chronic health outcomes correlated with inflammation and fat mass.

Body Composition Factors

Skeletal Muscle Mass & Lean Body Mass

Body composition includes several tissues, organs, cells, and body fluids such as blood and water. A particular feature that will be considered during this study is skeletal muscle mass tissue (SMM). Smooth muscles associated with organs and cardiac muscles are not included when defining SMM. SMM is comprised of muscle fibers and neuron motor units that assist in muscle contractions, nervous system communications, and movement. When SMM is lost during aging, these fibers and motor units have reduced capabilities for contracting said muscles. Muscle fibers are categorized by their contracting capabilities. Fast twitch fibers versus slow twitch fibers are of greater concern during muscle loss, as they are at higher risk of malfunctioning and being reduced in numbers with muscle loss (Keller & Engelhardt, 2014). Neuron motor units within muscles are susceptible to decreased functions associated with SMM loss. Firing rates of these motor units in aged muscles are estimated to be 35-40% lower than that of average adults muscles (Francis et al., 2017). In the average adult, 50% of body composition is made up of muscle tissue. During aging processes, it is estimated that about half of this tissue is lost suggesting that muscle mass comprises about 25% of an older adults body weight (Kob et al., 2015). Loss of SMM decreases the functionality of these muscle tissues. Functions and roles that muscles are responsible for include: body movement during physical activities by way of muscle contractions, process of metabolism, and storage of nutrients in the form of energy (Fielding, 2013). SMM steadily declines during aging, especially after an individual reaches the age of 50. Older adults who are sedentary or physically active experience age related loss of muscle

(Thomas, 2007). A loss of SMM hinders these body functions and an imbalance of body composition occurs further hindering aging processes.

Another element of body composition is lean body mass (LBM). LBM is overall bodyweight that includes muscles, organs, and essential fat. This can be confused with the term fat free mass (FFM). LBM and FFM are similar in that muscles, organs, and tissues are definitive of both, but LBM includes essential fat mass (Yu et al., 2013). FFM, on the other hand, is comprised of SMM, organs, and connective tissues (Müller, Geisler, Pourhassan, Glüer, & Bosy-Westphal, 2014). Essential fat and adipose fat tissue are not included in the definition of FFM. SMM is the predominant characteristic of LBM or FFM (Chuang, Chang, Lee, Chia-Yu Chen, & Pan, 2014). Atrophy or tissue wasting is attributed to LBM components of the liver, kidneys, spleen, skin tissues, bone, and skeletal muscles due to hindered protein build up during aging (Eynon, Yamin, Ben-Sira, & Sagiv, 2009). LBM loss during aging is the result of muscle atrophy that then affects an imbalance of body composition.

Muscle Strength

In conjunction with SMM declining, muscle strength also lessens with age. Research indicates that decreased muscle strength is of greater importance than loss of muscle mass because declining strength exceeds the amount of SMM loss. Studies report that decreased muscle strength is three times higher than decreased SMM (F. G. Di Girolamo et al., 2017). It is also reported that strength is a better indicator of decreasing functionality and health (Koster et al., 2011). Decreased strength is associated with increased risk of falls and deficits in performing activities of daily living. Reduced muscle strength can cause challenges with rising from chairs, lifting objects, walking speeds, balance, using stairs, or be able to use a strong handgrip (Hasegawa et al., 2008).

Multiple assessments are utilized for testing muscle strength in older adults. Three assessment tests are used for this particular study in testing muscle strength. The first highlighted assessment tool is handgrip strength. A dynamometer is a tool used to assess this and measures the strength by kilograms. Benefits of using handgrip strength assessments include: little training is required to perform assessment tests, requires small amounts of time for testing, and is constant measure in kilograms across populations (García-Peña C). Handgrip strength can categorize individuals having weak, intermediate, or normal muscle strength. According to recent statistics, weak strength is more likely as an individual ages. Five percent of individuals aged 60 and over had weak muscle strength according to handgrip measures and 13% had intermediate strength. Those who were aged 80 and over, in contrast, were more likely to have weak or intermediate strength with 19% having weak strength and 34% with intermediate muscle strength (Looker, 2015). The Foundation for the National Institutes of Health (FNIH) Sarcopenia Project developed and evaluated the best standards of assessing muscle weakness and low muscle mass in relation to sarcopenia. For the FNIH Sarcopenia Project, weak grip strength is <26 kg for men and <16 kg in women. Intermediate strength is classified as 26-31 kg, and 16-19 kg for men and women, respectively (Alley et al., 2014). Given these classifications, normal strength would then be considered to be a grip strength of above 32 kg for males and 20 kg for females.

Another assessment tool used for muscle strength is the 30 second sit-to-stand test. Sit-to-stand testing is commonly utilized to assess body function in older adults and is linked to predicting disability and mortality. Supplies needed for this test is an armless, straight backed chair and the individual being tested. Individuals are directed to sit and stand while being timed for 30 seconds. They are requested to not use hands or arms to help in performing the activity (Beasley et al., 2013). This test is used because sitting and standing are required in everyday activities. If older adults struggle in performing these activities, they may have the risk of developing sarcopenia and reduced muscle strength.

A third evaluation test is used for strength performance. The Tinetti Balance and Gait evaluation test considers different activities to indicate good balance and gait. Activities scored during the evaluation include: walking pace, safe walking, step length, step height, continuation of steps, saying, and walking posture/stance, sitting balance, rising attempts from a chair, standing balance, turning, and siting back down. The score between the two evaluations are combined to a maximum of 28 points. Those with scores less than 24 are at risk of falling due to poor muscle strength and performance (Martínez-Amat et al., 2013).

Muscle Function in Metabolism

Muscles assists in regulating metabolism of protein energy sources, converting nutrients into mechanical energy fuel, provide storage for energy sources that are used in brain function, immune properties, and stress responses (Phillips, 2003). With age-related loss of SMM, metabolic factors within muscle mechanisms are affected. Metabolism refers to the chemical process that break down (catabolism) or build up (anabolism) nutrient sources for energy and structural cell storage within the body (Yadav, 2013). A major form of anabolism in muscle tissues is the building up or synthesis of proteins to increase SMM. Age-related loss of SMM is associated with this protein synthesis or anabolism being inadequate to sustain muscle mass. Protein breakdown, known as catabolism, becomes imbalanced with protein synthesis causing the muscle loss associated with sarcopenia (G. F. Di Girolamo et al., 2014). Consumption of protein can initiate the anabolic mechanism. However, this mechanism, is diminished in older adult muscle tissue compared to young adults. Related research states that 0.05% of muscle fibers are synthesized at rest during a state of fasting. This rate is similar between ages. During protein consumption or physical exercise, this rate doubles in young adults, but is diminished in older adults (Mitchell et al., 2012). Inadequate protein consumption, decreases in exercise, and imbalances between the metabolic mechanisms associated with aging muscles inhibits functional roles of storage, metabolism, immune, and stress responses.

Fat mass and Inflammation

Another relation to body composition is the amount of fat versus muscle contributing to body weight. The amount of body fat increases in relation to older adults aging. In men, body fat is estimated to increase by 30% and in women, this is a 44% increase (Hurley, Bartlett, Witt, Thomas, & Taylor, 1997). Increased body fat is attributable to obesity prevalence and risk of developing chronic conditions. Fat contributes to body composition by way of adipose tissues. Adipose cells can be found through the body, but those that accumulate in the abdominal area pose concern for health (Lean, Han, & Tajar, 2011).   Research is now suggesting that fat and adipose cells are accumulating in muscle tissues. This is defined as ectopic adipose tissue deposition, as fat is accumulating in areas where it originally does not belong. Fat accumulation in muscle cells decrease SMM, strength, and metabolic functions suggesting sarcopenic obesity in older adults with obesity (Budui, Rossi, & Zamboni, 2015).

Larger amounts of adipose tissue accumulated throughout the aging body, are associated with increased inflammatory responses. Adipose tissues have the capabilities to release inflammatory protein cells known as cytokines. These inflammatory cells accelerate body composition changes during aging (Nicklas et al., 2012). Elevated cytokines create a fierce cycle of inadequate nutritional properties for energy metabolism and body stress reactions. Stress on the aging body is caused by arthritis, infections, tumors, pressure ulcers, and a malnutrition state. Each of these stresses trigger cytokines to be release by adipose tissue (Morley, 2001). Aging is associated with increased stress placed on the body resulting in inflammation for fat tissue.

Dietary Intake in Aging Population

Nutrition Concerns for Older Adults

Concerns of the aging population include decreased quality of life and higher risks of diseases that are related to adequate nutrition and wellbeing. Inadequate nutrition status affects older adults resulting in risks of sarcopenia and other conditions discussed previously. Factors that may lead to inadequate nutrition is altered taste and smell, difficulty in chewing and swallowing, altered gastrointestinal systems, eating environment, and sedentary lifestyles ("Position of the American Dietetic Association: Nutrition, Aging, and the Continuum of Care," 2000). Sickness, stress, decreased mobility are also associated with decreased dietary intakes. Appetites change with hormonal alterations and medication therapy (Holmes, 2006). Individuals experiencing several of these factors increase their risk for chronic disease and impaired quality of life.

Inadequate nutrition could be indicative of malnutrition in the forms of both undernutrition or over nutrition, which is distinguished by obesity. Obese adults in relation to being over nourished experience health issues due to a positive energy balance. This may seem optimistic in regards to health, however, this positive energy balance hastens fat to accumulate. Dietary patterns of older adults tend to focus on high caloric foods such as fats, but a less active lifestyle and decreased energy expenditure from metabolic properties. A pattern such as this causes weight gain and positive energy balance, but lacks the nutrients needed for daily physiological functions (Jura & Kozak, 2016). One concept to explain this is the protein leverage hypothesis which reflects on the need for obtaining the desirable amount of protein for physiological functions. Decreased protein intake as a result of higher fat and carbohydrate diets cause an amino acid deficiency and initiates a physiological mechanism that drives excess energy intake to fulfill the deficiency need. Fulfilling this deficiency is not prioritized with protein intake however, overconsumption of carbohydrates and fats fulfill the need and drives weight gain and obesity (Layman et al., 2015). Protein is a nutrient that is inadequately consumed in relation to this positive energy balance that affects sarcopenic obesity.

Function of Protein on Body Composition

Protein intake is imperative for many body functions including having a role in muscle anabolism and performing activities of daily living. Protein acts as an energy source for metabolic functions in muscles, body movement, and nutrient storage. Skeletal muscles hold 50-75% of all proteins that comprise the human body (Walker et al., 2011). For skeletal muscles to function properly, sufficient amounts of dietary protein should be consumed. Protein molecules are structured by amino acids that are essential for building muscle tissue (Landi et al., 2016). Essential amino acids are needed for these muscle functions. There are 9 out of 20 amino acids that are considered essential, defined by not originally being available in the body. Instead, they are found in dietary protein sources (Reeds, 2000). Amino acids are consumed in dietary proteins and are the essential elements used in muscle functions.

Dietary Sources of Protein

Sources of protein contain amino acids and nutrients essential for body composition and function. Protein can be found in animal or plant sources. Dairy and milk products, meat from animals, fish, and eggs are examples of animal sources. Plant sources that would contain some protein as well is soybeans, nuts, grains, vegetables, legumes, and certain fruits (Altorf-van der Kuil, Engberink, Geleijnse, Boer, & Monique Verschuren, 2012). Animal protein sources commonly are determined to be higher quality protein. Protein quality is determined by the amount of essential amino acids comprising the source defined by the World Health Organization (WHO). Animal protein products contain all of the 9 essential amino acids needed for physiological functions and are better absorbed by the aging individual. Plant products are not complete essential proteins as essential amino acids are missing from them (Weaver et al., 2015). Research involving protein intake from animal sources show that muscle fitness health is associated with increased intake of protein. In one study conducted with older adult participants, evidence showed that the only predictor for muscle mass preservation was consumption of animal protein sources (Gaffney-Stomberg, Insogna, Rodriguez, & Kerstetter, 2009). Essential amino acids found in animal sources determine body composition and muscle function in older adults.

Pork

Pork, a common red meat protein source, has been classified as a high quality protein containing all essential amino acids. Pork loin is used as the primary source of protein in the present study. Pork loin is considerably lean in regards to fat content. Research relates pork consumption to weight loss and improved body composition evidenced by decreased waist circumference and waist to hip ratios (Murphy et al., 2014; Murphy, Thomson, Coates, Buckley, & Howe, 2012). Consumption of pork creates an effect of feeling satisfied versus being hungry for a longer period of time than other protein sources. It also promotes weight loss or a negative energy balance, in contrast to a diet high in fat and carbohydrates (Charlton et al., 2011). Given this research, pork is a great source to use for a study relating protein intake to muscle and body composition changes in older adults. Furthermore, pork is one of the most widely consumed meat protein worldwide (Murphy et al., 2014).

Dietary Recommendations of Protein Intake

Increased dietary intake of protein sources is recommended for older adults to prevent age-related losses of muscle mass and function. The question of how much protein should be consumed to preserve muscle still remains unanswered, but current recommendations are established. The current Recommended Dietary Allowance (RDA) for protein intake for adults regardless of age, sex, and activity level is 0.8 g/kg/day. This RDA is based upon studies focusing on nitrogen balance within body systems. However, this method does not capture the changes in muscle mass, fat mass, total food intake, physical activity levels, or stress (trauma, disease, inflammation, infection) that occurs during aging (Gaffney-Stomberg et al., 2009). Current research reports that intakes above the RDA for protein show potential benefits for improving muscle function and older adult health (Layman et al., 2015). A protein intake that is between 1.0-1.5 g/kg/day is the suggested amount needed for these benefits to have pronounced effects in adults (Isanejad et al., 2016). Although, increased consumption of protein is beneficial for muscle health, weight loss, and metabolic function, there are consequences towards kidney function as well. High protein amounts cause kidneys to be overworked creating damaged cells and functions. Evidence suggests that pulse feeding patterns can reduce the risk of kidneys being damaged. Pulse feeding includes the idea of dividing protein into equal portions through the day, instead of loading the body with protein in one setting. Dividing protein intake throughout the day decreases strain placed on kidney function, increases metabolic processes of muscle, and improves muscle function and health in older adults (Arnal et al., 1999). Distributing equal amounts of protein (25-30g is recommended) across 3 or more meals per day in a pulse feeding pattern has the benefit of a 25% higher rate of muscle protein anabolism compared to unequal amounts of protein distribution throughout the day (Ten Haaf et al., 2018; van Loon et al., 2015). Following recommendations of increased protein intake throughout daily meals is evidenced to be beneficial for the aging population.

Typical Dietary Patterns Influencing Protein Intake

Older adults share behavioral tendencies that influence dietary intake of protein. Data trends present that 40% of older adults consumed less than the RDA for protein. Furthermore, about 16% consumed less than 75% of protein suggested by the RDA. These tendencies of inadequate protein intake, specifically animal sources, result from age-related factors. Factors such as food cost, access to food, and chewing/swallowing difficulties influence inadequate intake (Houston et al., 2008). Individuals consume most of their protein sources during the evening meal, instead of distributing protein sources throughout the day at other meal times and/or snacks. One study reports that older adults eat the most protein at the noon meal and that morning meals contained less than 20 g of protein. Additionally, these meals predominantly consisted of plant proteins such as grains (van Loon et al., 2015). Older adult eating patterns result in inadequate protein intake according to the RDA and pulse feeding recommendations for muscle protein synthesis and health.

Dietary Approaches to Stop Hypertension (DASH) Therapeutic Diet Pattern

Overview of DASH Diet

During the year 1997, a significant publication was introduced defining dietary intake effects on lowering blood pressure (L. J. Appel et al., 1997). The Dietary Approaches to Stop Hypertension (DASH) diet was presented as an effective intervention to lower blood pressure (Steinberg, Bennett, & Svetkey, 2017). During this time period, observational studies suggesting the role of nutrition on health, specifically on hypertension were being conducted. Nutrition factors associated with higher blood pressure were excessive consumption of salt, obesity from overabundance of fat in the diet, and above average alcohol consumption. Several other nutrient factors including: dietary fat consumption, cholesterol levels, protein intake, dietary fiber, and specific minerals (potassium, sodium, calcium, and magnesium) from foods have been studied in relation to blood pressure and could contribute to hypertension (Vogt et al., 1999). The DASH diet was greatly significant in scientific health research because of the hypothesis that individual nutrients synergistically acted on lowering or elevating blood pressure.

Previous studies individualized nutrients and the effects they had on blood pressure health. In the 20 years that the DASH diet has been utilized, it has demonstrated additional benefits towards cardiovascular health, metabolic processes, and an overall healthy lifestyle (Mellen, Gao, Vitolins, & Goff, 2008).

The DASH diet emphasizes fruit and vegetable intake, fibrous whole-grains, low fat meat and dairy products, increased amounts of nuts and legumes, and decreased sodium intake (Sayer, Wright, Chen, & Campbell, 2015). Incorporating these types of foods in a therapeutic diet results in adequate nutrition. Foods encompassed in the DASH diet are loaded with essential proteins, adequate fiber amounts, and sufficient amounts of vitamins and minerals that correlate with heart and blood pressure functions (Steinberg et al., 2017). Furthermore, the diet limits consumption of red meats, sweets, beverages containing sugar, overconsumption of sodium, and high amounts of saturated fats (Sacks et al., 2001). These factors tend to increase blood pressure and have deteriorating effects on health.

Protein Recommendations within DASH Diet

Animal protein sources are often limited in the DASH diet. Research from vegetarian studies show evidence that animal protein and byproducts are associated with higher blood pressures, however there is insufficient evidence to make this claim (Brussaard, Raaij, Stasse-Wolthuis, Katan, & Hautvast, 1981; Nowson, Wattanapenpaiboon, & Pachett, 2009). Protein sources that are acceptable for consumption in the DASH dietary pattern are poultry, fish and seafood, low fat dairy, and plant proteins. Typically, red meat sources such as pork and beef, are not recommended for high consumption in the DASH diet. This is solely based on the strategy to reduce the amount of saturated fats consumed from fatty red meats (Nowson et al., 2009). Insufficient evidence towards these recommendations of limiting animal sources are present.

Prevalence has been placed current research to detect the effects of protein on blood pressure. There is no significant difference between plant and animal proteins in current studies. Animal sources, which are higher in essential amino acids, could have a larger effect on lowering blood pressure than plant sources (Rebholz et al., 2012). Animal sources and red meats are typically higher in saturated fats. There are sources of these meats that are considered lean and low fat. Pork loin for instance has low amounts of fat, but contains all of the essential amino acids. Although red meat is not recommendation for consumption daily in the DASH diet, one study has incorporated red meats to develop associations between the two. They found that including lean red meats in DASH diet patterns shows decreased cholesterol levels that improve blood pressure (Roussell et al., 2014). Including lean red meats, such as pork, in a DASH diet pattern is associated with healthy benefits of lowering blood pressure.

Benefits of the Therapeutic DASH Diet Pattern

Considering the DASH diet for interventional therapy in blood pressure control was a main focus for the research conducted. By performing a feeding study to test effects of dietary patterns was significant for research, as a diet patterns focuses on whole food consumption rather than just focus on a single nutrient (L. J. Appel et al., 1997). Obviously, the DASH diet is beneficial to individuals with high blood pressure. Another benefit of the diet pattern is that total cholesterol was lowered in individual with hyperlipidemia. By reducing both blood pressure and cholesterol, the risks of developing cardiovascular disease is also lowered (Folsom, Parker, & Harnack, 2007). DASH dietary measures promotes relaxation of blood vessels to help blood flow throughout the body. This creates less resistance and pressure put on vessel walls associated with vessel stiffening due to aging (Sacks, 2015). Benefits of this decrease blood pressure in age related hypertension. Combined benefits of the DASH diet contribute to overall health and promote wellness interventions that are therapeutic.

Role of the DASH Diet and Pork Intake in Chronic Disease Interventions

A goal of this study was to use the DASH diet to improve muscle composition and muscle function related to age related sarcopenia. However, sarcopenia is associated with hypertension, obesity, and sarcopenic obesity in older adults. Dietary measures are intervention strategies to reduce the effects of these chronic conditions. Compliance to the DASH diet significantly reduces blood pressure in older adults, and has added benefits of reduced cholesterol and promoting weight loss to reduce risks of chronic diseases (Racine, Lyerly, Troyer, Warren-Findlow, & McAuley, 2012). The addition of pork for a protein source in the diet increases the beneficial effects. Pork protein consumption can help an individual feel fuller and satisfied for longer periods of time, increases the use of nutrients in metabolism and energy expenditure, and promotes weight loss due to greater loss of fat than muscle. Protein assists physiological processes to preserve muscle mass and function, while preventing fat mass to accumulate. One study shows that increased protein consumption is associated with a decreased body fat percentage and increased FFM (Soenen & Westerterp-Plantenga, 2010). Furthermore, dietary protein intake within a therapeutic diet at each meal from pulse feeding strategies stimulates muscle anabolism hindering the effects of sarcopenic obesity. Protein intake also has beneficial effects on weight loss evidenced by decreased BMI, waist circumference, fat mass, and percentage of fat (Verreijen et al., 2015). Increasing protein consumption within DASH dietary recommendations influences muscle health in older adults

CHAPTER 2: OBJECTIVES AND AIMS

Objective: The primary goal of this study was to determine the role of lean unprocessed pork as a part of the DASH diet on measures of body composition and muscle fitness in older adults.

Aim 1: To test the hypothesis that compliance with consuming foods in the DASH dietary pattern influences body composition in older adults.

Rationale: Age related changes in body composition occur in older adults affecting their overall health and quality of life. Persistent body composition changes such as increasing fat mass, and reduced muscle mass causes the development of chronic conditions that lead to poor quality of life and risk of mortality. Older adult populations are growing in size in relation to increased life expectancy and decrease birth rates. Although the population is experiencing this growth, they are also experiencing chronic health conditions that are affected by body composition changes related to age. Furthermore, poor dietary intake influences these changes as well. Older adults who comply with a healthy dietary pattern such as the DASH diet, will experience healthy aging in regards to body composition changes.

Design: Study participants will comply with a DASH dietary pattern for 12 weeks that is provided to them by research staff. Breakfast, lunch, dinner and 2 snacks were provided following DASH dietary recommendations. Baseline (week 0) body composition data was collected and measured every 3 weeks until study end (week 12) for a total of 5 different time points (weeks 0, 3, 6, 9, and 12). Fat free mass (kg), lean body mass (kg), height (cm), weight (kg), BMI (kg/m^2), waist and hip circumference (cm), waist-hip ratio, % body fat, absolute fat mass (kg), skeletal muscle mass (kg), fat mass (kg), resting energy expenditure (kcal), systolic blood pressure (mmHg), diastolic blood pressure(mmHg), and total body water(kg) were all assessed for changes in body composition

Aim 2: To test the hypothesis that consumption of daily lean unprocessed pork as the primary protein source in the DASH diet maintains muscular fitness in adults 65 years and older.

Rationale: Age related loss of muscle mass and changes in body composition effect muscle strength and function in older adults. Reduced muscle fitness as a result of age related loss of muscle mass effects overall health and activities of daily living. Reduced muscle function hinders an individual from partaking in activities independently. Muscles are made up of protein molecules that built up and are synthesized as a result of protein intake in the diet. Older adults benefit from higher lean protein intakes to preserve this loss of muscle mass and function.

Design: At each assessment time point (weeks 0, 3, 6, 9, and 12), participants engaged in a set of activities that assessed muscle strength and function. Researchers evaluated each individual performing the activities based on handgrip strength, sit-to-stand chair exercises, gait and balance tests, and activities of daily living questionnaires. From these assessments, researchers obtained data to determine participants with low, intermediate, or high muscle strength and function.

Research Impact

Developing research based around this objective is of significance for the future. As the aging population is on the rise, healthcare professionals will see greater development of age related conditions as a result of inadequate dietary intake. Aging individuals experiencing age related conditions will be of great importance in public health care research. Interventions will be needed that impact the aging population positively. This includes developing dietary patterns and recommendations that are beneficial to older adults. Incorporating daily amounts of lean protein sources, such as pork in a DASH dietary pattern preserves muscle mass and function in older adults (Dietary Guidelines for Americans 2015-2020). Older adults who comply with such a dietary pattern will stunt the effects of aging longer and preserve their muscles for daily activities. Complying with a healthy dietary pattern such as the DASH diet, also reduces the risk for developing chronic obesity, hypertension, diabetes, and heart disease. This is of importance to hinder the rising rates of these chronic conditions.

CHAPTER 3: METHODOLOGY

Methods

Design

A randomized controlled feeding study was utilized to investigate the effects of dietary pork intake on body composition, muscle fitness, and function. Nine participants were recruited from the Brookings, SD area fitting the older adult age group of 65 years or older. Recruited individuals were randomly assigned to consume either a total of 3 ounces (oz) or 6 oz of pork daily. Each participant, regardless of pork consumption amount, received 3 meals and 2 snacks daily for 12 weeks. IRB approval was given by the SDSU Review Board before the study began. Consent was given by each participating individual before beginning the study to fully agree to eating the controlled diet for 12 weeks and being assessed every 3 weeks. Before receiving the food for their first day of the study, they were required to have their baseline (week 0) fitness assessments performed. Body composition, muscle function, and strength were assessed every 3 weeks starting at week 0 of the study, and ending at week 12. Exercise science professionals assisted with assessments using different evaluation methods to measure each assessment factor that defined musculoskeletal health. Between the 3 week assessments, individuals participated in the feeding portion of the study. They received daily meals and snacks including the portion of pork they were assigned. During the 12 week study, individuals could only consume the food that study researchers prepared for them. Participants would eat meals in the study food lab 2-3 times a week and would receive to-go meals for the days that they were not eating in the lab. By requiring participants to eat in the food lab, compliance could be observed.

Recruitment

The recruitment process was conducted in the Brookings, SD and local rural area. Flyers were created to be distributed throughout the area in areas that individuals could read the information about the study. Faculty offices on campus were one of the places that flyers and recruitment were conducted. Neighborhoods with large portions of older adult residents were also a place of recruitment. Other recruitment focus areas were community churches and local businesses that received business from a large portion of adults 65 years and older. To attract participants during recruitment, a compensation amount of $390 was provided to each participant. Portions of the compensation amount were given to each participant after each 3 week assessment. Individuals who were recruited, contacted study researchers, and were invited to come for interview. During the interview, participants would receive further information about the study and sign the consent form to participate if they chose to do so. They then proceeded to scheduling the week 0 assessment and were randomly assigned to their pork intake group.

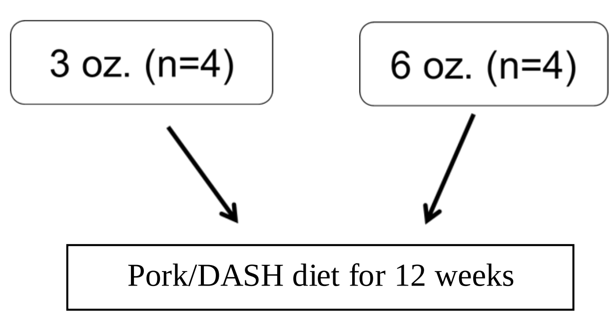
Participants

Recruited individuals were 65 years or older at their week 0 baseline assessments. The average age of the participants was 70 years old. During the study, the youngest participant was 65, while the oldest participant was 77 years old. At baseline, there was 9 participants total, 5 males and 4 females, and all participants were classified as Caucasian. However, one male did not complete the study and ended after one week of participating on the study. Sixty five years old was the chosen minimum age for the study as it fits the definition of what is classified as an older adult in regards to age related effects on health and muscles. Individuals recruited for the study were impacted with signs of muscle mass loss, reduced strength and function, changes in dietary intake, and chronic health conditions such as obesity, hypertension, and diabetes. This particular age group was chosen for the study and is an ideal group that the effects of dietary protein intake are observed through changes in musculoskeletal health and overall wellbeing in older adults.

Study participants began the controlled feeding study at different time intervals as recruitment continued throughout a period of 3 months. In a 6 month period, 9 individuals were recruited for the study. All but 1, completed from week 0 to week 12. Due to prior health concerns that limited their dietary intake and affected compliance with study diet, this one participant discontinued one week after their baseline assessment. At the final 12 week assessment, which marked the study-end, a total of 8 participants completed the study. Four participants received 3 oz. of pork daily, while the other 4 received 6 oz. There was an equal number of males and females that completed the study. However, they were randomized into each intake group to prevent skewing results of all males or females being in one intake group. The outline of how the intake groups are divided are shown in **Figure 1.**

Figure 1: **The outline of how the pork intake groups were divided.**

N=number of participants for each intake group



Materials and Procedures

Diet Intake

Balanced meals were given throughout the 12 week study. A 7-day cyclic menu was created for the study with meals repeating each week. Creating this type of menu prevented variations within the diet that could skew results data. The menu followed the recommendations of the Dietary Approaches to Stop Hypertension (DASH) diet. Recommendations are included in **Table 1.** The primary source of protein was from lean pork loin. Lean pork loin was provided at each meal defined as breakfast, lunch, and dinner. Pork was distributed evenly between these 3 meals for each intake group. Therefore, the 3 oz. intake group received 1 oz. of pork at each meal and the 6 oz. group received 2 oz. of pork at each meal. All food items included in the menu, were purchased, prepared, and weighed out to the nearest gram by research staff in the food laboratory located in Wagner Hall, room 416. On average, each participant received 1555 kilocalories daily. Caloric variations between the intake groups averaged a difference of about 120 kilocalories due to the increased portion size of pork in the 6 oz. group. Another variation in relation to pork intake was the in the amount of sodium. There is about a 50 milligram difference between the intake groups as a larger portion of pork contained more sodium. Although there is this difference, the amount of sodium is lower in both intake groups compared to the amount recommended by the DASH diet. **Table 1** also presents this difference in kilocalories along with how the DASH serving recommendations are comparable to this study diet menu servings. Averages from the total of each day's daily counts are shown. In **Table 2,** the 7 day menu is displayed showing the variety of food items and the amounts being served at each meal.

Table 1: Study serving sizes for each intake group compared to DASH recommendations

(For each pork intake group, this table shows the amount of average serving of each food group and/or nutrient of importance in the diet for study purposes)

Food Group	**DASH SERVING** (daily unless noted otherwise)	**3 oz. Pork** (daily unless noted otherwise	**6 oz. Pork** (daily unless noted otherwise
Grains	5-6	5	5
Vegetables	3 to 4	5	5
Fruits	4	4	4
Dairy	2 to 3	2.5	2.5
Lean Meat	3 to 4	3	6
Legumes	3 per week	1.5 weekly	1.5 weekly
Fats/Oils	1	1.5	1.5
Sweets	3 or less (weekly)	0	0
Sodium	<2300mg	1445	1494
Calories	this age group=1600*	1500	1610
Macronutrients	Carbohydrates: 45-65%	64%	60%
	Fat: 20-30%	16%	17%
	Protein: 15-25%	19%	23%
Saturated Fat	<6-10%	6.5%	6.5%

("DASH Eating Plan,") https://www.nhlbi.nih.gov/health-topics/dash-eating-plan
*1600 calories based on USDA Recommendations
(*Dietary Guidelines for Americans 2015-2020*)

Menu Development

NutritionPro computer software was utilized to develop the study menu. On this software program, recipes were entered into the program using foods from the United States Department of Agriculture (USDA) food order guide that is commonly used for food service operations in schools and hospitals. The software program has the ability to calculate various nutrition information about food products such as calorie amounts, sodium, vitamins, protein and fat amounts. By applying this feature, the menu could be standardized with the amounts that are used in comparison to the DASH diet.

Table 2: The DASH menu containing pork provided to the participants for 12-wks

Day	Breakfast	Lunch	Dinner
Monday	Pork Tenderloin slice, cooked (28.35 g) 1 large egg, cooked (50 g) WW Toast (2 slices, 84 g) Mixed Fruit Cup (113 g) Beverage	Pork-Waldorf Salad: Pork Tenderloin slice , cooked (28.35 g) Mixed greens (82.5 g) Apple, chopped (182 g) Grapes (151 g) Celery (40 g) Light dressing packet (30 g)	Roasted Pork and Potatoes: Pork Tenderloin slice, cooked (28.35 g) Small potatoes, canned (158 g) Green beans, frozen (123 g) Orange (131 g) Milk, low-fat (8 fl oz)
Tuesday	WW Waffle, homemade (75 g) Pork Tenderloin slice , cooked (28.35 g) Applesauce (122 g) Beverage	Pork Burrito Bowl: Ground beef, cooked (28.35g) Onions, frozen (57.5 g) Bell peppers, frozen (74.5 g) Tomatoes, canned (90 g) Brown rice (92.5g)	Pork Soft Tacos: Ground pork, cooked (28.35 g) Small WW tortilla (41 g) Shredded lettuce (36 g) L/F cheese (28.35 g) Fruit cup (113 g) Milk, low-fat (8 fl oz)
Wednesday	Pork Tenderloin slice , cooked (28.35 g) Oat-raisin granola cereal, (102 g) Milk, low-fat (8 fl oz) Banana, medium (118 g) Beverage	Pork Tenderloin Sandwich: Pork Tenderloin slice, cooked (28.35 g) WW bread (2 slices, 92 g) Romaine lettuce (47 g) Tomato slice (90 g) Orange (131 g)	Ground Pork Pizza: Ground pork, cooked (28.35 g) Homemade dough (70 g) L/S tomato sauce (61 g) L/F cheese (28.35 g) Pineapple, canned (122 g) Milk, low-fat (8 fl oz)
Thursday	Pork Tenderloin slice, cooked (28.35 g) 2 WW blueberry pancakes, homemade (47 g each) Blueberries, frozen (39 g) Beverage	Pork and Vegetable Soup Pork Tenderloin slice, cooked (28.35 g) L/S vegetable soup, canned (245 g)	Broccoli-Pork Stir-fry: Pork chunks, cooked (28.35 g) Brown rice (92.5 g) Broccoli, frozen (182 g) Fruit cup (113 g) Milk, low-fat (8 fl oz)
Friday	Pork Tenderloin slice, cooked (28.35 g) 1 WW bagel (85 g) Grapes (151 g) Beverage	Pork and Beans Ground pork, cooked (28.35 g) L/S Black beans, canned (50 g) L/S Red kidney beans, canned	Pork Lasagna: Ground pork, cooked (28.35 g) WW noodle (28 g) L/S tomato sauce (150 g) Diced Tomatoes (90 g) L/F cheese (28.35 g)

		(50 g) Mixed Salad Greens (82.5 g) Light dressing packet (30 g) Apple (182 g)	Green Beans, frozen (135 g) Milk, low-fat (8 fl oz)
Saturday	Pork Tenderloin slice, cooked (28.35 g) Oatmeal packet, cooked (234 g) Banana, medium (118 g) Apple, medium (182 g) Beverage	<u>Pork-Spinach Salad:</u> Pork tenderloin slice, cooked (28.35 g) Spinach, fresh (42.5 g) Orange slices (65.5 g) Cucumber slices (52 g) Green Peppers (74.5 g) Strawberries (144 g) Light dressing packet (30 g)	<u>Pork Quesadilla:</u> Ground pork, cooked (28.35 g) 2 WW tortillas (82 g) L/F cheese (28.35 g) L/S Black beans, canned (50 g) Onions, frozen (28.75 g) Grapes (151 g) Milk, low-fat (8 fl oz)
Sunday	Pork tenderloin slice, cooked (28.35 g) Multigrain cheerios, (29 g) Milk, low-fat (8 fl oz) Banana, medium (118 g) Beverage	<u>BBQ Pork Sandwich:</u> Pork patty, cooked (28.35 g) WW bun (50 g) Cucumber slices (52g) Tomato slices (123 g) BBQ Sauce (22.5 g) Fruit cup (113 g)	<u>Pork Goulash:</u> Ground pork, cooked (28.35 g) WW pasta, cooked (140 g) L/S Tomato Sauce (60 g) L/S Tomato Paste (40 g) Diced Tomatoes (90 g) L/S Black Beans (50 g) Frozen Green Beans (62 g) Onions, frozen (92 g) Orange, medium (131 g) Milk, low-fat (8 fl oz)

(DASH menu that includes daily dietary pork tenderloin used for the study each week. 7 day menu that repeats each week)
WW: Whole wheat; L/F: Low-Fat; L/S: Low-sodium
Daily snack will include a L/F fruit yogurt (4 oz; Yoplait) and L/S V8 juice (8 fl oz; Campbell Soup Company)

<u>Food Lab Equipment and Procedures</u>

In this controlled feeding study, participants are considered an at risk population. This means that as older adults they are more susceptible to foodborne illness and disease. To prevent foodborne illness in the study, ServSafe procedures were followed throughout the study duration. ServSafe is a national certification program established by the National Restaurant Association to provide prevention and safe handling food programs to facilities around the country. Instructions on food preparation, food storage, kitchen sanitation, serving food, and cleaning were followed to ensure that the lab kitchen facility was an environment in which older adults could safely eat in and consume food from. Before and during the study, research staff were trained on basic ServSafe food safety procedures and some were certified in ServSafe prior to the study. Research staff followed procedures appropriately to prevent illness that would cause skewed results. All food served to participants was bought from the local grocery store weekly to ensure freshness and quality. Food items were stored in a lab on campus in proper refrigerators, freezers, and pantries. Refrigerators were kept at temperature below 40°F and freezers were below 0°F to prevent bacterial growth on foods that were being utilized in the study.

Electronic scales were used in the food lab to weigh food ingredients to the nearest gram amount. Each item being served was portioned individually instead of utilizing batch cooking methods. Portioning items for participants was an important method maintain the controlled feeding part of the study.

Participants ate in the lab kitchen 2-3 times a week. They were served on clean plates that are stored appropriately in the kitchen until service times. They were offered water, coffee, juice, or tea to drink. While participants ate, research staff prepared to go meal bags that participants could take home. This ensured that participants were compliant with the study.

Physical Assessments and Equipment

Along with the controlled feeding, another component of the research study was to assess participants by physical measurements and tests to demonstrate the outcomes of the pork intake and controlled feeding. In collaboration with the exercise science department, physical assessments were completed by exercise science staff and students. Each assessment approximately took an hour to complete as various measurements were taken by using several different instruments.

The measurements taken are indicators of musculoskeletal health. Included were body anthropometric measurements for body composition, fitness tests, and functionality evaluations. Fat free mass (kg), lean body mass (kg), height (cm), weight (kg), BMI (kg/m^2), waist and hip circumference (cm), waist-hip ratio, % body fat, absolute fat mass (kg), skeletal muscle mass (kg), fat mass (kg), resting energy expenditure (kcal), SBP (mmHg), DBP (mmHg), and total body water (kg) were all assessed for changes in body composition. A Detecto medical beam balance was used to measure participants' body weight and height. BMI was calculated from these measurements. The circumferences for hips and waist were measured by a Gulick tape measure and measured twice in each participant to detect human error if feasible. Body composition measurements utilized air displacement plethysmography (COSMED, Inc) when assessed. Estimations of resting energy expenditure will be made by using indirect calorimetry (Parvo Medics TrueOne® 2400, Salt Lake City, UT) after a 2 hour fasting period in a temperature and humidity controlled laboratory in the exercise department facilities. Using this method includes measuring baseline expired gases for 5 minutes to establish a stable condition in the participant. After the beginning 5 minutes, oxygen consumptions and expended calories will be measured for 15 minutes while participant is seated and at rest. Handgrip strength, sit-to-stand, Tinetti gait and balance, and the Fullerton Advance Balance Scale test were used to assess strength and muscle function. To assess handgrip strength, a dynamometer was used, which measures the force of each hand on the device. Within the

Fullerton tests, assessments are made based impairments of activities such as: standing with eyes closed, reaching for objects, turning around, taking stairs, standing on one leg, jumping, and posture.

The Katz and Lawton Scales were used to asses overall body function for activities of daily living. Activities of daily living can become challenging with onset of sarcopenia and the loss of muscle strength and function. Included activities that may be of difficulty for older adults are cooking, housekeeping, shopping, driving, walking, and bathing (Franchow, Butner, Kraybill, Williams, & Suchy, 2010). To assess activities of daily living (ADL's) in this particular study, both the Katz Index and Lawton Scale Assessment were used. The Katz Index measures the patient's ability to independently perform ADL's. A total of 6 ADL's are assessed including: bathing, dressing, toileting, transferring, continence, and feeding. They get one point for each function that is able to be performed without assistance. Full function is indicative of a maximum score of 6, moderate impairment is a score of 4, and 2 or less is suggestive of severe functional impairment in ADL tasks (Shelkey & Wallace, 2001). Another assessment tool for ADL's is the Lawton scale. This tool goes beyond the Katz assessment as it measures 8 functions that are more detailed and require higher function of independence to perform. Included activities assessed are: ability to use a phone, shopping, food preparation/cooking, housekeeping, ability to handle finances, taking medications, using various forms of transportation, and doing laundry. A maximum score of 8 indicates high functionality and an individual is considerably independent (Graf, 2008). Using both assessment in the study is indicative of high to low muscle function related to sarcopenia.

Statistical Analysis

All data analysis used IBM SPSS for Windows (Version 23, IBM Corporation, Armonk, NY). Various statistical tests were used to analyze the data. A t-test was used to compare the means of each intake group to show the differences in each intake group separate from each other. Interaction comparisons were analyzed as well using 2-way repeated measures analysis of variance for effect of diet with time. In each of these statistical tests, alpha <0.05 was used as the hypothesis to show significance.

CHAPTER 4: RESULTS

Table 3: Baseline data divided by demographics
Average baseline data for total number of participants and within sex groups

	Overall	Male				Female			
	Total	Overall	65-69	70-74	75-79	Overall	65-69	70-74	75-79
	n=8	n=4	n=3	n=0	n=1	n=4	n=1	n=2	n=1
Demographics									
Age (years)	70±4.6	69±5.7	66.0±1.2	0.0±0.0	77.0±0.0	72±3.3	67.0±0.0	72.0±0.0	75.0±0.0
Height (cm)	166.6±10.1	173.4±8.6	175.1±9.7	0.0±0.0	168.5±0.0	159.7±6.4	160.0±0.0	155.5±4.2	168.0±0.0
Body Composition									
Weight (kg)	95.9±20.7	95.6±24.3	92.4±28.7	0.0±0.0	105.4±0.0	96.1±20.1	88.2±0.0	101.8±32.8	92.5±0.0
BMI (kg/m²)	34.8±8.8	31.5±6.3	29.7±6.2	0.0±0.0	37.1±0.0	38.1±10.5	34.5±0.0	42.5±15.9	32.8±0.0
Waist Circumference (cm)	109.5±21.4	103.8±19.4	100.1±22.0	0.0±0.0	114.8±0.0	115.2±24.7	105.6±0.0	122.1±40.3	110.7±0.0
Hip Circumference (cm)	120.9±17.3	114.2±13.0	111.0±13.9	0.0±0.0	123.6±0.0	127.7±20.1	121.5±0.0	135.8±30.8	117.7±0.0
WHR	0.9±0.1	0.9±0.1	0.9±0.1	0.0±0.0	0.9±0.0	0.9±0.1	0.9±0.0	0.9±0.1	0.9±0.0
%Fat (%)	40.7±7,9	35.4±6.5	33.5±6.5	0.0±0.0	41.0±0.0	46.0±5.4	47.8±0.0	48.2±6.2	40.0±0.0
AFM (kg)	39.4±13.2	33.9±11.1	30.8±11.3	0.0±0.0	43.2±0.0	44.8±14.3	42.2±0.0	50.1±22.1	37.0±0.0
FFM (kg)	56.5±12.8	61.7±16.0	61.6±19.6	0.0±0.0	62.2±0.0	51.3±7.4	46.0±0.0	51.9±10.8	55.5±0.0
LBM (kg)	63.4±11.4	66.1±14.1	66.3±17.3	0.0±0.0	65.4±0.0	60.7±9.2	56.6±0.0	63.9±14.6	58.3±0.0
SMM (kg)	68.8±16.7	75.8±20.6	75.8±25.2	0.0±0.0	75.6±0.0	61.7±9.8	55.8±0.0	62.2±15.0	66.8±0.0
FM (kg)	86.5±28.9	74.6±24.1	67.8±24.5	0.0±0.0	94.8±0.0	98.4±31.5	93.5±0.0	109.4±49.1	81.1±0.0
TBW (kg)	94.4±20.3	99.6±25.6	99.3±31.3	0.0±0.0	100.5±0.0	87.5±11.5	75.0±0.0	97.7±0.0	89.8±0.0
REE (kilocalories)	1604.1±384.3	1809.7±434.9	1788.0±530.0	0.0±0.0	1874.0±0.0	1398.5±206.8	1210.0±0.0	1391.0±226.3	1602.0±0.0
REE-kg (kilocalories/kg body weight)	17.1±3.9	19.0±2.6	19.5±3.0	0.0±0.0	17.8±0.0	15.1±4.3	13.7±0.0	14.8±7.0	17.3±0.0
SBP (mmHg)	128.6±13.7	133.5±15.3	134.3±18.6	0.0±0.0	131±0.0	123.7±11.9	113.0±0.0	134.0±2.8	114.0±0.0
DBP (mmHg)	75.9±4.5	76.2±2.9	77.0±3.0	0.0±0.0	74±0.0	75.5±6.2	73.0±0.0	80.5±2.1	68.0±0.0
Strength									
Handgrip-Right (kg)	29.9±11.2	36.7±11.6	39.8±12.1	0.0±0.0	27.5±0.0	23.1±5.8	16.5±0.0	24.0±5.7	28.0±0.0
Handgrip-Left (kg)	27.9±8.9	32.9±8.0	34.2±9.3	0.0±0.0	29±0.0	22.9±7.3	20.5±0.0	20.0±8.5	31.0±0.0
Function Assessments									
Sit-to Stand (reps)	12±3.3	11.5±3.4	12.7±3.1	0.0±0.0	8.0±0.0	12.5±3.7	7.0±0.0	14.5±0.7	14.0±0.0
Tinetti Gait (score out of 12)	11.8±0.3	12.0±0.0	12.0±0.0	0.0±0.0	12.0±0.0	11.7±0.5	12.0±0.0	11.5±0.7	12.0±0.0
Tinetti Balance (score out of 16)	15.1±1.1	15±1.4	15.7±0.6	0.0±0.0	13.0±0.0	15.2±1.0	16.0±0.0	15.0±1.4	15.0±0.0
Fullerton (score out of 16)	12.2±3.3	13.5±3.0	14.7±2.3	0.0±0.0	10.0±0.0	11.0±3.5	6.0±0.0	13.0±1.4	12.0±0.0
Katz (score out of 6)	5.7±0.5	6.0±0.0	6.0±0.0	0.0±0.0	6.0±0.0	5.5±0.6	6.0±0.0	5.5±0.7	5.0±0.0
Lawton (score out of 8)	8±0	8.0±0.0	8.0±0.0	0.0±0.0	8.0±0.0	8.0±0.0	8.0±0.0	8.0±0.0	8.0±0.0

Abbreviations: Body Mass Index (BMI), Waist to Hip Ratio (WHR), Percent Body Fat (%Fat), Absolute Fat Mass (AFM), Free Fat Mass (FFM), Lean Body Mass (LBM), Skeletal Muscle Mass (SMM), Fat Mass (FM) Total Body Water (TBW), Resting Energy Expenditure (REE), Resting Energy Expenditure per kilogram (REE-kg), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP),

All data is written as mean ± standard deviation

In **Table 3,** baseline characteristics of the 8 participants are shown. For demographic characteristics, the average age for male participants was 69 and 72 for females. Overall, the average age of participants was 70 years old. Height measurements were taken at baseline only and not at weeks 3, 6, 9, or 12 as it is a variable expected to not change throughout the study or be affected by other variables. Height of males is

Table 4: BMI classification and Nutritional Status
*According to BMI classification, a nutritional status of underweight, normal weight, or overweight can be defined using this chart

Body Mass Index (BMI)	Nutritional Status
Below 18.5	Underweight
18.5 -24.9	Normal
25.0 – 29.9	Pre-Obesity
30.0-34.9	Pre-Obesity I
35.0 – 39.9	Pre-Obesity II
Above 40	Pre-Obesity III

http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi

generally expected to be taller than females, which is shown by the average male height of 173.4 cm and average female height of 159.7 cm. Height measurements are directly related to BMI and are assessed for calculating BMI in association with study assessments. The average BMI of all participants is 34.8 kg/m^2 which is considered to be Obese Class 1 according to the BMI/Nutritional status classification chart that the World Health Organization utilizes. This classification chart is displayed by **Table 4.** Baseline averages of weight were 95.6 kg and 96.1 kg for males and females. The overall average weight was 95.9 kg and is directly associated with the BMI classifications given in **Table 4.**

Comparisons between the intake groups showed no significance of body composition, strength, or function changes. Evaluating time effects on body composition, strength, and function showed significant changes regardless of intake groups. **Table 5** shows changes in body composition measures at each intervention week (0, 3, 6, 9, & 12) point across time. The first p-value for each variable is the significance value across time, while the second p-value is the significant value for comparing baseline (week 0) data to the study end data (week 12). Significant ($p<0.05$) changes across time are seen in weight ($p=0.000$), BMI ($p=0.000$), waist circumference ($p=0.000$), hip circumference ($p=0.000$), % body fat ($p=0.000$), fat mass ($p=0.000$), and balance score ($p=0.002$) such that decrease was observed over the intervention period. Although significant changes were not seen in all variables, changes were observed. Weight, BMI, waist and hip circumference, percent body fat, FM, TBW, SBP and DBP decreased. The following variables did not decrease across time: FFM, LBM, and SMM. Resting energy expenditure increased by 60 kilocalories across time, but was not a significant change. Significance between baseline and study end are seen in the following variables: weight ($p=0.001$), BMI ($p=0.001$), % body fat ($p=0.005$), AFM ($p=0.003$), and FM ($p=0.000$). Significant ($p<0.05$) changes across time are seen in weight ($p=0.000$), BMI ($p=0.000$), % body fat ($p=0.030$), LBM ($p=0.015$), SMM ($p=0.029$), and SBP ($p=0.041$). Although significant changes were not seen in all variables, changes were observed. Weight, BMI, waist and hip circumference, percent body fat, FM, TBW, SBP and DBP decreased. The following variables did not decrease across time: FFM, LBM, and SMM. Resting energy expenditure increased by 60 kilocalories across time, but was not a significant change. Significance between baseline and study end are seen in the following variables: body weight ($p=0.001$), BMI ($p=0.001$), waist circumference ($p=0.000$), hip circumference ($p=0.001$), % body fat ($p=0.005$), fat mass ($p=0.000$), and right handgrip strength ($p=0.000$). Lean body mass ($p>0.05$) and skeletal muscle mass ($p>0.05$) were well preserved.

Table 5: Changes in Body composition across time
Time effects and baseline/study-end differences for indicators of body composition and muscle fitness in older adults consuming 3oz (n=4) or 6oz (n=4) of pork daily as a part if the DASH diet for 12-wks

	Weeks of Intervention					
Body Composition Variables	**0**	**3**	**6**	**9**	**12**	**P-value**
Weight (kg)	95.9±7.3	93.6±7.3	92.6±7.2	90.7±7.1	89.5±6.8	0.000 *0.001
BMI (kg/m²)	34.8±3.1	34.0±3.1	33.6±3.1	33.0±3.0	32.5±2.9	0.000 *0.001
Waist Circumference (cm)	109.5±7.6	106.8±7.5	106.6±7.8	103.4±7.2	103.1±7.2	0.000 *0.000
Hip Circumference (cm)	120.9±6.1	119.1±6.7	118.4±6.8	115.8±5.8	115.5±6.6	0.000 *0.001
WHR	0.9±0.0	0.9±0.0	0.9±0.1	0.9±0.2	0.9±0.3	0.494 0.090
%Fat (%)	40.7±2.8	39.8±3.3	37.9±3.6	37.8±3.7	36.6±3.6	0.000 *0.005
FFM (kg)	56.5±4.5	55.7±4.2	56.8±4.5	55.7±4.4	55.9±4.2	0.180 0.500
LBM (kg)	63.4±4.0	62.5±3.7	63.0±3.8	62.3±3.8	62.4±3.5	0.472 0.319
SMM (kg)	68.8±5.9	67.9±5.6	69.3±5.7	67.8±5.7	67.7±5.4	0.159 0.423
FM (kg)	86.5±10.2	83.1±11.3	78.3±11.6	76.7±11.5	73.3±11.2	0.000 *0.000
TBW (kg)	94.4±7.7	92.8±7.2	94.4±7.5	92.6±7.4	92.3±7.1	0.103 0.232
REE (kilocalories)	1604.2±135.9	1571.7±121.8	1677.6±131.8	1715.2±155.2	1664.8±136.4	0.847 0.724
REE-kg (kilocalories/kg body weight)	17.1±1.4	17.2±1.3	18.8±1.9	19.6±2.1	19.1±1.8	0.322 0.260
SBP (mmHg)	128.6±4.8	130.5±6.2	127.4±3.5	124.4±2.0	125.5±4.6	0.721 0.318
DBP (mmHg)	75.9±1.6	73.9±1.5	72.7±2.3	75.6±2.3	71.4±4.0	0.504 0.166

Abbreviations: Body Mass Index (BMI), Waist to Hip Ratio (WHR), Percent Body Fat (%Fat), Absolute Fat Mass (AFM), Free Fat Mass (FFM), Lean Body Mass (LBM), Skeletal Muscle Mass (SMM), Fat Mass (FM) Total Body Water (TBW), Resting Energy Expenditure (REE), Resting Energy Expenditure per kilogram (REE-kg), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP),

Data is written as mean ± standard error

*=significant from baseline to study end

Table 6: Changes in strength and function across time
Time effects and baseline/study-end differences for indicators of muscle strengthn and function in older adults consuming 3oz (n=4) or 6oz (n=4) of pork daily as a part if the DASH diet for 12-wks

	Weeks of Intervention					
Strength and Function Variables	**0**	**3**	**6**	**9**	**12**	**P-value**
Handgrip - Combined (kg)	57.8±6.9	57.3±6.2	59.9±7.3	57.6±6.6	61.4±6.2	0.782 0.093
Handgrip - Right (kg)	29.9±4.0	28.9±3.5	30.8±3.9	29.8±3.4	31.7±3.0	0.679 *0.000
Handgrip - Left (kg)	27.9±3.1	28.4±2.9	29.1±3.6	27.8±3.4	29.7±3.3	0.446 0.132
Sit-to-Stand (repetitions in 30 sec)	12.0±1.2	12.5±1.0	13.5±0.9	13.4±1.0	13.2±0.8	0.197 0.190
Tinetti Gait (score out of 12)	11.9±0.3	11.9±0.3	12±0.0	12±0.0	11.7±0.7	(-) 0.685
Tinetti Balance (score out of 16)	15.1±1.1	15.6±0.5	16±0.0	15.8±0.3	15.8±0.3	0.002 0.080
Fullerton (score out of 16)	12.2±3.3	11.4±3.7	13.1±2.5	12.5±3.2	13±2.8	0.197 0.476
Katz (score out of 6)	5.7±0.5	5.7±0.5	5.7±0.5	5.7±0.5	5.9±0.3	(-) 0.351
Lawton (score out of 8)	8±0.0	8±0.0	8±0.0	8±0.0	8±0.0	(-) (-)

Data is written as mean ± standard error
(-)=no p-value could be calculated
*=significant from baseline to study end

Table 6 shows the changes in muscle strength across time. Muscle strength was tested with handgrip strength and sit-to-stand tests. Significance in muscle strength was not identified across time or from baseline to study end. Even though significance was not shown, an increase in handgrip strength was observed as it increased by 3.6 kg from week 0 to week 12. Repetitions of sitting to standing in 30 second increased as well by 1.2 repetitions. This is also shown in **Table 7.** **Table 7** shows this from the mean differences between each intervention week. Negative mean difference show increases in relation to this.

Shown in **Table 7**, is the significant values (p<0.05) with mean differences for each intervention week compared to baseline. By showing these values, results can be given of when significant changes occurred during the study interventions. Changes in weight, BMI, and FM were significant at each week of intervention. Whereas, hip circumference, % body fat, and AFM did not show significant changes until week 6 and after. Waist circumference showed significance at week 9 and week 12.

Table 7: Significant changes based on each week compared to baseline
Results show where significant changes occur at each week intervention compared to baseline measures. Differences of intervention mean values are shown

	Week	Week	P-Value	Mean Difference
Weight (kg)	0	3	*0.011	2.3±0.7
	0	6	*0.002	3.3±0.7
	0	9	*0.001	5.2±0.9
	0	12	*0.001	6.3±1.2
BMI (kg/m²)	0	3	*0.007	0.8±0.2
	0	6	*0.002	1.2±0.2
	0	9	*0.001	1.8±0.3
	0	12	*0.001	2.3±0.4
Waist Circumference (cm)	0	3	0.074	2.7±0.7
	0	6	0.105	2.9±0.8
	0	9	*0.001	6.1±0.8
	0	12	*0.000	6.4±0.7
Hip Circumference (cm)	0	3	0.143	1.8±1.1
	0	6	*0.043	2.5±1.0
	0	9	*0.003	5.1±1.1
	0	12	*0.001	5.4±0.9
WHR	0	3	0.344	0.0±0.0
	0	6	0.375	0.0±0.0
	0	9	*0.043	0.0±0.0
	0	12	0.09	0.0±0.0
%Fat (%)	0	3	0.166	0.9±0.6
	0	6	*0.015	2.8±0.9
	0	9	*0.030	2.9±1.1
	0	12	*0.005	4.1±1.0
AFM (kg)	0	3	0.406	1.5±0.6
	0	6	*0.030	3.6±0.8
	0	9	*0.023	4.4±0.9
	0	12	*0.003	5.8±0.9
FFM (kg)	0	3	0.154	0.8±0.5
	0	6	0.661	-0.3±0.6
	0	9	0.291	0.8±0.7
	0	12	0.5	0.6±0.9
LBM (kg)	0	3	0.119	0.9±0.5
	0	6	0.721	0.4±1.1
	0	9	0.165	1.0±0.7
	0	12	0.319	1.0±0.9

SMM (kg)	0	3	0.271	0.8±0.7
	0	6	0.573	-0.5±0.9
	0	9	0.359	1.0±1.0
	0	12	0.423	1.0±1.2
FM (kg)	0	3	*0.027	3.4±1.2
	0	6	*0.003	8.1±1.8
	0	9	*0.002	9.8±2.1
	0	12	*0.000	13.2±1.8
TBW (kg)	0	3	0.13	1.6±0.9
	0	6	0.982	0.0±1.2
	0	9	0.218	1.8±1.3
	0	12	0.232	2.1±1.6
REE (kilocalories)	0	3	0.749	32.5±97.5
	0	6	0.358	-73.4±74.6
	0	9	0.522	-110.9±164.7
	0	12	0.724	-60.6±164.7
REE-kg (kilocalories/kg body weight)	0	3	0.93	-0.1±1.0
	0	6	0.121	-1.7±1.0
	0	9	0.166	-2.5±1.6
	0	12	0.26	-2.0±1.7
SBP (mmHg)	0	3	0.793	-1.9±6.9
	0	6	0.777	1.2±4.2
	0	9	0.359	4.2±4.3
	0	12	0.318	3.1±2.9
DBP (mmHg)	0	3	0.364	2.0±2.1
	0	6	0.156	3.1±2.0
	0	9	0.847	0.2±1.2
	0	12	0.166	4.5±2.9
Handgrip Strength (kg)	0	3	0.731	0.5±1.4
	0	6	0.206	-2.1±1.5
	0	9	0.885	0.2±1.2
	0	12	0.093	-3.6±1.8
Sit-to Stand (reps)	0	3	0.275	-0.5±0.4
	0	6	0.064	-1.5±0.7
	0	9	0.12	-1.4±0.8
	0	12	0.19	-1.2±0.9

Abbreviations: Body Mass Index (BMI), Waist to Hip Ratio (WHR), Percent Body Fat (%Fat), Absolute Fat Mass (AFM), Free Fat Mass (FFM), Lean Body Mass (LBM), Skeletal Muscle Mass (SMM), Fat Mass (FM) Total Body Water (TBW), Resting Energy Expenditure (REE), Resting Energy Expenditure per kilogram (REE-kg), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP)

*Significance is p<0.05

Mean differences are shown as mean difference ± standard error

CHAPTER 5: DISCUSSION AND CONCLUSIONS

This study observed the effect of pork intake as a part of the DASH diet on body composition, muscle strength, and muscle function in adults 65 years and older. Age related loss of muscle mass and function is related to decreased protein intake and poor dietary patterns in the older adult population (Pennings et al., 2011). Increased obesity rates from poor dietary intake and body composition changes are prevalent in the older adult population and considered to be a risk factor for mortality, decreased quality of life, sarcopenic obesity, cardiovascular disease, hypertension, and diabetes (Chen, Chuang, Liu, Hsu, & Pan, 2015). In this study, observed positive body composition and muscle function effects from a balanced dietary pattern such as the DASH diet and consistent protein intake are evidenced by significant data.

Dietary Pork Protein

Several research studies have evidenced the effect of protein supplementation and specific amino acid supplements on muscle mass and function. This study however, utilized dietary protein sources, not supplements. Dietary protein sources are better absorbed and utilized by body cells. Although no significant results were found between the protein intake groups, significant changes occurred across time. One important aspect associated with this was the even distribution of protein amount across 3 meals a day. Preservation of FFM, LBM, and SMM are evidenced similarly to other studies. Distributing protein evenly across daily meals is associated with higher LBM and appendicular LBM in older adults. Recommendations of about 30g of protein per a meal are given (Gray-Donald et al., 2016). In this present study, the 3 oz pork intake group received 28.35 g for a total of 85 g total per day. For the 6 oz intake group, they received twice the amount at each meal, 56.7 g per meal and 170 g daily, respectively. The intake group receiving the 3 oz of pork daily followed current recommendations of protein intake supported by Dietary Reference Intakes published by the Food and Nutrition Board (Volpi et al., 2012). Higher intakes were studied in correlation to preserving muscle mass, strength, and function during the aging process.

Current research suggests that older adults require higher protein intakes than the recommendations that are published at present. It is important to note that animal proteins in comparison to plant proteins are associated with preserving muscle strength and function. Pork is an animal protein that provides all essential amino acids evidencing muscle function improvement in regards to grip strength and physical mobility. Although this current study found no results related to pork intake amounts, other studies have evidenced that mobility limitations were 50% greater risk in protein intake groups that received <0.7g/kg/day (Houston et al., 2017). The present study may have not found significant results similar to other studies because of a small sample size (n=8).

Body Composition Changes

In the present study, significant changes occurred in body composition measures as shown in the results section. Observations of weight decreased by about 6 kg contributing to a decreased BMI measure as well. Results show that the loss of weight is associated with the loss of fat mass, and not loss of muscle mass measures (LBM, FFM, SMM). This supports the idea of protein intake helps with preserving muscle mass in older adults, but promotes loss of weight in relation to decreased fat in the body to reduce prevalence of sarcopenic obesity. Study trends show that decreased body weight is associated with loss of muscle mass and LBM. This present study contrasts these trends with the effects of LBM, FFM, and SMM preserved compared to weight and fat mass loss. In contrast, one study reported that participants who lost more than or equal to 5% of their body weight also lost about 0.5 kg of SMM over the study period. This is also comparable to loss of LBM contributed to 44-58% of total weight lost in a 3-4 year period (Gray-Donald et al., 2013). Comparable to another study of evaluating body composition changes, fat loss was found in 2 different intake groups. One intake group met the RDA of 0.8 g/kg/day, while the other intake group was twice this amount. The study results found that both intake groups had contributable loss of fat mass, but the RDA protein group lost muscle mass as well. In the double protein group, muscle mass was preserved showing that higher protein intakes could result in preservation of muscle composition associated with aging (Milan et al., 2017).

The DASH diet primarily uses poultry and seafood as main animal protein sources. Reasoning for this is because red meats such as pork contain higher amounts of fat compared to white meat sources. In this present study, lean pork loin was used as the primary protein source within the DASH dietary pattern. The DASH diet is an intervention method to control high blood pressure, especially in the older adult population. In a similar feeding study, pork was used as a protein substitution in a DASH dietary pattern. Using lean pork in the study did not negatively influence blood pressure indicating that consumption of pork and a DASH dietary pattern provides beneficial effects of lowering blood pressure (Sayer et al., 2015). This evidence is consistent with the results of the present study. Systolic blood pressure significantly decreased across time. Across time, systolic blood pressure decreased by 3-4 mmHg (p=0.041). Average baseline systolic blood pressure was 128.6 mmHg while at study end it dropped to 125.5

mmHg. Although these blood pressures are considered to be pre-hypertensive according to the Centers of Disease Control, blood pressure changes are significant in regards to dietary patterns ("High Blood Pressure Fact Sheet," 2016).

Muscle Strength and Function Effects

Sarcopenia is not only highlighted by the contrasted changes of fat and muscle mass, muscle strength and function is also a considerable portion of the definition. With reductions of muscle mass and weight, evidence is shown that muscle strength decreases as well. In one diet study, a vegetarian like diet (protein came from milk and eggs) was used for food and calories restriction to promote weight loss. Within the results of this study, weight loss occurred, but so did muscle mass. Furthermore, loss of muscle mass was accompanied by reduced muscle strength by 8.7 to 9.3 % (B. Kim et al., 2017). Although this study design is opposite of the present study, it evidences that dietary protein, specifically animal protein has an impact on muscle strength.

Hand grip strength is one method to assess muscle strength in this population, as it is a quick, accessible method that requires little equipment and instruction. In this present study, handgrip strength was measured in each hand and scores were added together for a composite score. Alone, the right hand grip strength increased by 1.8 kg from baseline to study end which was a significant change in strength ($p=0.000$). The left hand grip change was not significant but increased 1.8 kg as well during the study. This compares to a study where consumption of different nutrients are assessed for influencing grip strength. The study showed that eating fish as a protein source more than once a week improved grip strength by 3 kg. A decrease in grip strength is related to decreased quality of life and impaired ADL’s (Robinson et al., 2008).

Limitations

This study presented limitations and challenges. Being set in a rural location with a small population, it was difficult to recruit participants of appropriate age, as travel to the campus lab was a factor in their participation. As a result, the small sample size may have not been large enough to produce significant results for some variables assessed. Requiring participants to eat in the campus lab 2-3 times a week helped assessing compliance to the provided diet. In contrast to this, with participants not eating every meal in the presence of research staff limited assessing compliance to the diet. Another limitation found in this study is that all participants were Caucasian, therefore data cannot be used across other population races/ethnicities.

Conclusion and Future Directions

Observed changes in body composition and muscle strength related to age and dietary patterns are evidenced in this study and others. Further evidence and research is suggested to define more significant results. Larger sample sizes will better highlight evidence in the future. Other research in similar areas will produce stronger evidence as well. Studying other adult age groups could define when dietary interventions should begin to preserve muscle mass and strength in older adults. Maybe increasing protein intake at or during early adult stages will be associated with improved muscle function in older adult groups, decreasing the prevalence of sarcopenia, obesity, hypertension, sarcopenic obesity, and other chronic conditions within the aging population. Other questions to ask for future research directions include how does childhood and adolescent dietary patterns and lifestyle affect individuals when aging starts to occur? At what age could the increase of protein intake be recommended at? Does protein intake differ between older adults living independently at home or those living in assisted care facilities? These factors may have a role in improved or impaired body composition, muscle strength, and functionality in older adult populations.

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