

**Exploring Cross-Sectional Relationships between Health Literacy, Dietary Intake,
Physical Activity, and Anthropometric/Biological Variables among Residents in
Southwest Virginia**

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ABSTRACT

BACKGROUND: Low health literacy and numeracy are significant problems facing the United States. Recent research focuses heavily on the role health literacy and numeracy play in perception of disease risk, health care costs, all-cause mortality, and access to care; however, there has been relatively little emphasis on the relationships between health literacy or numeracy with health promotion behaviors, such as nutrition or physical activity. As our nation continues to face challenges with the high prevalence of obesity and other chronic diseases, it is increasingly important to understand the role that health literacy and numeracy play in nutrition and physical activity behaviors, as well as in the prevalence and control of chronic disease.

PRIMARY AIMS: The proposed research is embedded within a larger randomized-control trial, Talking Health, which is a 2-arm behavioral trial targeting residents in eight counties in southwest Virginia with sugar-sweetened beverage (SSB) consumption as the primary outcome. The primary aims of this cross-sectional study, using baseline Talking Health data, are to 1) examine correlations among health literacy and numeracy measures, namely the Newest Vital Sign (NVS), separated by reading (NVS Reading) and math (NVS Math) scores, the Rapid Estimate of Adult Literacy in Medicine (REALM), and the Subjective Numeracy Scale (SNS); 2) explore the relationships between demographic factors and the NVS, REALM, and SNS scores; 3) determine the relationships between the NVS, REALM, and SNS and dietary quality [i.e. Health Eating Index (HEI) scores], physical activity behaviors, and anthropometric and biological variables (body mass index, blood pressure, fasting blood lipids, and fasting blood glucose); and 4) determine if NVS, REALM, and SNS scores predict metabolic syndrome (MetS), while controlling for relevant demographic factors.

METHODS: Eligibility requirements for the study include being 18 years of age or older, having reliable access to a telephone, drinking ≥ 200 kilocalories of SSB per day, and being a resident of Southwest Virginia. Using previously validated instruments and standardized data collection protocol, a variety of baseline variables was collected on 264 participants. Health literacy was measured using the NVS and REALM and health numeracy was measured using the SNS. Dietary intake was measured via three 24-hour dietary recalls and HEI scores were calculated. Physical activity behaviors were assessed using the Godin Leisure Time Exercise Questionnaire. Weight was measured using a calibrated digital Tanita scale (Model: 310GS), height was measured using a portable research-grade stadiometer, blood pressure measurements were made with an OMRON automated oscillometric device (Model: HEM-907XL), and fasting blood samples were obtained via a finger stick and the CardioChek PA system was used to assess blood glucose, cholesterol, and triglycerides. MetS scores were

determined based on an adaptation of the National Cholesterol Education Program guidelines. Statistical analysis included descriptive statistics, simple correlations (Pearson bivariate), one-way ANOVAs, and regression models.

RESULTS: Of 264 enrolled participants (mean age 41.1 ± 13.5 years; 92.0% Caucasian; 81.8% female; 30.6% \geq high school education; 42% $>$ \$15,000 annual income), 33.7% were classified as having a high probability of low health literacy or possibility of low health literacy as measured by the NVS, 19.7% had less than a high school reading level as measured by the REALM, and 45.4% had low health numeracy as measured by the SNS. Additionally, 78.8% were overweight or obese and 29.0% meet the criteria for metabolic syndrome. Nine of the ten correlations between the NVS Total, NVS Reading, NVS Math, REALM, and SNS were statistically significant ($p < .01$, two-tailed). NVS scores were found to be significantly different by age ($F = 2.36$, $p = .05$), race ($F = 4.49$, $p = .03$), education level ($F = 20.97$, $p < .001$), and income ($F = 13.88$, $p < .001$); while REALM scores were only significantly different by race ($F = 3.74$, $p = .05$), education level ($F = 21.06$, $p < .001$), and income ($F = 6.80$, $p < .001$). SNS scores were significantly different by gender ($F = 12.40$, $p = .001$), education level ($F = 11.01$, $p < .001$), and income ($F = 14.45$, $p < .001$). Only systolic blood pressure, diastolic blood pressure, and strength training activity was found to be significantly different by health literacy and/or numeracy level; however, when controlling for hypertension medication use and/or demographic variables, only the relationship between health literacy (i.e., NVS) and strength training activity remained significant ($R^2 = 0.09$, $p = .01$). Finally, health literacy and numeracy were not found to be predictive of metabolic syndrome while controlling for demographic variables.

DISCUSSION: Although numerous demographic factors were related to baseline health literacy and numeracy levels, anthropometric/biological variables, physical activity behaviors, and diet quality did not differ by health literacy and health numeracy level, with the exception of systolic blood pressure and strength training activity. This research helps to fill the gaps in the literature surrounding the prevalence of health literacy, health numeracy, and health promoting behaviors and chronic disease among rural residents in medically underserved counties in southwest Virginia. While few cross-sectional relationships were found, future research from this RCT should examine if health literacy and health numeracy moderates or mediates intervention changes in anthropometric/biological variables, physical activity behaviors, diet quality, and metabolic syndrome scores.

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Table of Contents

Chapter 1: Literature Review	1
<u>Health Literacy and Health Numeracy</u>	1
<u>Measures of Health Literacy and Health Numeracy</u>	3
<u>Trends in Health Behaviors and Clinical Indicators</u>	6
<i>High Rates of Sugar-Sweetened Beverage Intake</i>	6
<i>Increasing Rates of Physical Inactivity</i>	7
<i>Increasing Rates of Overweight and Obesity</i>	8
<i>Trends in Clinical Indicators</i>	9
<u>Observations about Health Literacy</u>	11
<i>Health Literacy and Dietary Behaviors</i>	11
<i>Health Literacy and Physical Activity Behaviors</i>	13
<i>Health Literacy and Body Mass Index</i>	14
<i>Health Literacy and Clinical Indicators</i>	15
<u>Observations about Health Numeracy</u>	17
<i>Health Numeracy and Dietary Behaviors</i>	17
<i>Health Numeracy and Physical Activity Behaviors</i>	18
<i>Health Numeracy and Body Mass Index</i>	18
<i>Health Numeracy and Clinical Indicators</i>	19
<u>Reviews and Interventions targeting Health Literacy and Health Numeracy</u>	20
<i>Health Literacy</i>	20
<i>Health Numeracy</i>	26
<u>Conclusions</u>	28
<u>Aims and Hypotheses</u>	29
Chapter 2: Exploring Cross-Sectional Relationships between Health Literacy, Dietary Intake, Physical Activity, and Anthropometric/Biological Variables among Residents in Southwest Virginia	31
<u>Introduction</u>	31
<u>Methods</u>	33
<i>Study Design</i>	33
<i>Target Population</i>	34
<i>Recruitment and Eligibility</i>	34
<i>Data Collection and Outcome Measures</i>	35

<i>Data Analysis</i>	37
<u>Results</u>	38
<i>Participants</i>	39
<i>Correlation of Health Literacy and Numeracy Measures</i>	39
<i>Differences in Health Literacy and Numeracy Status by Demographic</i>	
<i>Characteristics</i>	39
<i>Differences in Anthropometric/Biological Variables, Physical Activity, and Dietary</i>	
<i>Quality</i>	40
<i>Metabolic Syndrome</i>	42
<u>Discussion</u>	42
Chapter 3: Future Implications	48
<u>Introduction</u>	48
<u>Future Implications</u>	49
<u>Conclusion</u>	51
References	60
Appendices	68
Appendix A: IRB Approval.....	68
Appendix B: Informed Consent.....	70
Appendix C: Newest Vital Sign (NVS).....	73
Appendix D: Rapid Estimate of Adults Literacy in Medicine (REALM).....	76
Appendix E: Subjective Numeracy Scale (SNS).....	78
Appendix F: Godin Leisure Time Physical Activity Questionnaire.....	80

List of Tables

Table 1. Demographic Characteristics of Participants at Baseline.....	52
Table 2. Correlations between Health Literacy and Health Numeracy (n = 264).....	53
Table 3. Differences in Health Literacy and Numeracy Status by Demographic Characteristics.....	54
Table 4. Body Mass Index, Blood Pressure, and Fasting Plasma Glucose.....	55
Table 5. Fasting Blood Lipids.....	56
Table 6. Physical Activity Behaviors.....	57
Table 7. Average Daily SSB Intake and Healthy Eating Index Scores.....	58
Table 8. Using Health Literacy and Demographic Variables to Predict Metabolic Syndrome (n = 264)	59

Chapter 1

Literature Review

Health Literacy and Health Numeracy

Low health literacy is a significant problem facing the United States by affecting over 80 million individuals (*Agency for Healthcare Research & Quality, 2011*). It has been prioritized in the last decade by the Department of Health and Human Services, including goals to increase health literacy in both *Healthy People 2010* and *Healthy People 2020*. Health literacy encompasses a variety of different skills and is most often defined as “the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions” (*AHRQ, 2011*). Limited health literacy is associated with poorer health outcomes such as increased incidence of chronic disease and poorer disease markers, as well as decreased use of preventive health services (*Berkman et al., 2004*). Furthermore, low health literacy has been linked to increased hospitalizations and emergency care and poorer ability to interpret medication levels and health messages. Among the elderly, low health literacy is associated with poorer overall health status and higher mortality rates (*Berkman et al., 2011*). Limited health literacy has been found to be higher in certain subpopulations including those living below the poverty line, the elderly, individuals with fewer years of completed education, those who live in rural areas, and those who do not speak English as their first language (*Rudd, 2007; Paasche-Orlow et al., 2005; Zahnd et al., 2009; Baker et al., 2007*). Additionally, limited health literacy may also be able to explain racial disparities in health outcomes (*Berkman et al., 2011*).

In addition to inadequate health literacy, another problem plaguing the health of the nation is inadequate health numeracy. Currently, there is no widely accepted definition of health numeracy, but it can generally be defined as “the degree to which individuals have the capacity to access, process, interpret, communicate, and act on numerical, quantitative, graphical,

biostatistical, and probabilistic health information needed to make effective health decisions” (Golbeck et al., 2005). While roughly 80 million Americans have poor health literacy skills, even more have poor quantitative skills. The National Assessment of Adult Literacy found that over 110 million Americans, or approximately 35% of the population, have inadequate numeracy skills (Huizinga et al., 2008). In fact, roughly 22% of Americans scored at a performance level that corresponds to having the ability to solve only single-operation math problems (Fagerlin et al., 2007). There is a strong link between literacy and numeracy, but basic or poor numeracy skills are still prevalent in individuals with adequate literacy (Cavanaugh et al., 2008) and in some cases, numeracy and not literacy has been related to outcomes (Cavanaugh et al., 2008; Huizinga et al., 2008; Osborn et al., 2013).

Health numeracy is a relatively new field and has only recently been prioritized; therefore, there has been little research on the relationships between health numeracy and health outcomes (Golbeck et al., 2005). Inadequate health numeracy can considerably impact health. Numeracy skills are important in weight management through the monitoring of daily calorie intake and expenditure (Huizinga et al., 2008); in reading and interpreting food labels (Huizinga et al., 2008); in diabetes self-management (Cavanaugh et al., 2008); and in understanding disease risk (Cavanaugh et al., 2008).

To date, the majority of health literacy and health numeracy studies have been conducted in clinical settings (Allen et al., 2012). There is a gap in the literature related to the role of health literacy and numeracy in non-clinical settings as well as the role of health literacy and numeracy in health promotion behaviors, such as physical activity and nutrition. In order to more adequately prepare for and address our nation’s health needs, there is a critical need for further research exploring how health literacy and numeracy are associated with health outcomes, including physical activity, diet, and disease prevalence (Golbeck et al., 2005).

Measures of Health Literacy and Health Numeracy

There are several instruments for measuring health literacy including the Test of Functional Health Literacy in Adults (TOFHLA), the Rapid Estimate of Adult Literacy in Medicine (REALM), and the Newest Vital Sign (NVS). However, there is no gold standard for measuring health literacy, as no instrument is comprehensive and each has limitations (*Berkman et al., 2011; Baker, 2006*). Although each instrument measures different skills (i.e. numeracy, reading, etc.), no test measures all skills as illustrated by the definition of health literacy.

The TOFHLA is a valid, reliable indicator of adults' ability to read health-related materials, such as labeled prescription vials and other hospital documents (*Parker et al., 1995; Baker, 2006*). It was developed using hospital materials and consists of a 50-item reading comprehension and 17-item numerical ability test that can take up to 22 minutes to administer (*Parker et al., 1995*). There are two shortened versions of the TOFHLA available for use: the Short Test of Functional Health Literacy in Adults (S-TOFHLA) and the TOFHLA abbreviated. The S-TOFHLA is a 36-item reading comprehension test and takes approximately 7 minutes to administer while the TOFHLA abbreviated includes 36 reading comprehension items and 17 numerical ability items and takes approximately 12 minutes to administer (*Paasche-Orlow et al., 2005; Parker et al., 1995*). While the TOFHLA and the TOFHLA abbreviated both include numeracy components, the numeracy measures of these instruments do not best assess health numeracy. The questions only require simple quantitative skills (i.e. keeping clinic appointments and monitoring blood glucose) which makes it difficult to generalize participants' ability to perform higher-level calculations (*Fagerlin et al., 2007*).

The REALM is a 66-item word recognition and vocabulary test that measures pronunciation and familiarity of relevant medical terminology and takes about 2-3 minutes to administer (*Paasche-Orlow et al., 2005; Murphy et al., 1993*). The test is scored by adding the

number of words that the patient pronounced correctly and this number corresponds to the patient's estimated grade range (*Murphy et al., 1993*). The REALM does not include any numeracy components.

Lastly, the NVS is a 6-item test that measures the ability to read and apply information from a nutrition label on the back of one pint of ice cream. The test takes approximately three minutes to administer and identifies patients as either having a higher probability of limited health literacy (indicated by a score of less than two on the NVS), a possibility of limited health literacy (a score of 2-3), or adequate health literacy (a score of 4-6) (*Weiss et al., 2005*). Similar to the TOFHLA, the NVS only tests a narrow range of mathematical skills (*Osborn et al., 2013*).

In order to optimally measure health numeracy, several instruments have been recently developed including the Subjective Numeracy Scale (SNS) and the General Health Numeracy Test (GHNT). There are other measures of numeracy available, but some have been criticized for having little application to health or being too lengthy and taxing on participants while others are only disease-specific (*Osborn et al., 2013; Lipkus, Samsa, & Rimer, 2001; Huizinga et al., 2008; Apter et al., 2006*). The SNS is a valid, reliable self-report measure of "perceived ability to perform various mathematical tests and preference for the use of numerical versus prose information" (*Zikmund-Fisher, Smith, Ubel, & Fagerlin, 2007*). The 8-item test has no mathematical questions. It asks participants four questions about their perceived mathematical ability and four questions about their preference for the way that information is presented, yet it is still highly correlated with common numeracy measures (*Fagerlin et al., 2007*). Unlike other numeracy measures, the SNS can be administered in less time, is more pleasant for the participant, and results in less missing data (*Fagerlin et al., 2007*). However, there are limitations with this instrument. The SNS is not a measure of objective numeracy and does not test specific mathematical skills. Additionally, the equivalence of the SNS and objective

numeracy tests and the minimum SNS score required to predict adequate performance can vary in each application due to context (*Zikmund-Fisher, Smith, Ubel, & Fagerlin, 2007*).

The GHNT, developed by Osborn and colleagues, is the most recent measure of health numeracy. This instrument has two forms, the GHNT-21 and the GHNT-6, which indicates how many questions each form contains; both are valid and reliable (*Osborn et al., 2013*). The instrument includes items that aim to assess a wide range of quantitative skills such as number hierarchy, nutrition management, medication compliance, and calculating disease risk (*Osborn et al., 2013*). Because the GHNT has only recently been developed, additional research is needed to provide support for the instrument and prove its value in other contexts. Additionally, the GHNT-21 appears to be a more robust measure of health numeracy than the GHNT-6 and further evidence is warranted to determine whether the GHNT-6 is equal to the lengthier version (*Osborn et al., 2013*).

As stated previously, no current test for health literacy is comprehensive; each measure evaluates a specific component of health literacy, such as reading ability, vocabulary, health knowledge, or numeracy (*Berkman et al., 2011; Baker, 2006*). There is a need for new, more comprehensive measures of health literacy (*Baker, 2006*); however, in the meantime, it is important for researchers to utilize the current instruments available that measure the various aspects of health literacy and health numeracy in conjunction with each other in order to gain a more complete understanding of an individual's true health literacy status. Furthermore, many of the available instruments have different categories for health literacy levels and researchers often collapse these levels differently (*Parker et al., 1995; Baker, 2006*), making comparisons across studies sometimes difficult.

Trends in Health Behaviors and Clinical Indicators

High Rates of Sugar-Sweetened Beverage Intake

Between the 1960s and early 2000s, sugar-sweetened beverage (SSB) consumption rose dramatically, increasing from an average of 236 kilocalories (kcal) per day in 1965 to an average of 458 kcal per day in 2002 (*Duffey & Popkin, 2007*). While current trends in SSB consumption show decreased consumption in 2009-2010, Americans are still exceeding the recommendation of eight ounces per day and far exceeding the recommendation set by the American Heart Association of no more than 450 kcal per week from SSB (*Kit et al., 2013; Johnson et al., 2009*). This downward trend has been observed across all age groups (*Kit et al., 2013*) but SSBs still provide a substantial amount of daily calories. Currently, SSBs account for approximately 10% of total energy intake in adults (*Johnson et al., 2009*) and are the biggest contributor to added sugar intake in the United States with soft drinks alone accounting for 33% of total added sugars consumed (*Johnson et al., 2009; Guthrie and Morton, 2000*) and all categories of SSBs combined accounting for approximately 57% of added sugars consumed (*Guthrie and Morton, 2000*). Research indicates that those with fewer years of completed education and those whose family income is below the poverty line are more likely to consume SSBs (*Brown et al., 2011*). Sugar-sweetened beverages are defined as any beverage that includes a caloric sweetener (*Centers for Disease Control and Prevention, 2010*) and include soft drinks, fruit drinks, sports drinks, tea and coffee that have been sweetened with sugar, energy drinks, and sweetened milk.

National survey data suggests that excessive consumption of added sugars is contributing to the overconsumption of discretionary calories and, thus, adding to the rise in obesity (*Johnson et al., 2009*). In fact, the increased consumption of SSBs in the past several decades parallels the rise in obesity rates (*Bray, Nielsen, & Popkin, 2004; Vartanian et al., 2007*). Obesity rates doubled between 1980 and 2004 (*Khan et al., 2009*) and in 2010, more

than 35% of adult men and women were obese and 16.9% of children and adolescents were obese (Ogden *et al.*, 2012). Not only have SSBs been linked to the escalating obesity epidemic, but there is also a strong body of literature that ties increased SSB consumption to an increased risk for coronary heart disease (Johnson *et al.*, 2009; Nielsen and Popkin, 2004; Fung *et al.*, 2009), hypertension (Brown *et al.*, 2011; Cohen *et al.*, 2012), hypertriglyceridemia (Johnson *et al.*, 2009), type II diabetes (de Koning *et al.*, 2011; Montonen *et al.*, 2007; Schulze *et al.*, 2004), and dental caries (Ismail *et al.*, 2009; Vartanian *et al.*, 2007).

Increasing Rates of Physical Inactivity

Physical inactivity is also a growing problem in the United States and has been associated with the rise in overweight and obesity. Additionally, lack of exercise has been associated with a higher risk for early death, heart disease, stroke, type II diabetes, depression, and some cancers (CDC, 2014). The benefits of physical activity are also well documented and include not only weight management, but also positive effects on blood lipids (Bouillon *et al.*, 2011), blood pressure (Nelson *et al.*, 1986), and insulin sensitivity (Kriska *et al.*, 1994; Rosenthal *et al.*, 1983). However, despite the known benefits of exercise and the consequences of sedentary behavior, only 48% of all US adults meet the 2008 Physical Activity Guidelines which call for 150 minutes of moderate-intensity physical activity per week and strength training exercises on two or more days per week (CDC, 2014).

Research indicates that individuals living in the South are less likely to meet physical activity recommendations than those living in the West, Northeast, and Midwest regions of the country. Additionally, people with less education and those whose family income is below the poverty line are less likely to meet physical activity recommendations (CDC, 2014). Due in part to these same factors, the prevalence of overweight and obesity are higher in areas that are subject to greater economic and health disparities (Patterson *et al.*, 2004; Williams *et al.*, 2008),

such as rural southwest Virginia (Zoellner et al., 2012; Huttlinger et al., 2004). These discrepancies may be related to greater incidence of low health literacy in rural areas, as limited health literacy has been shown to be more prevalent in individuals with less education and those living in poverty (Kutner et al., 2006; Paasche-Orlow et al., 2005); however, there is not only a lack of research on the consequences of health literacy interventions on physical activity and diet behaviors, but there is also limited research that demonstrates how health literacy and other associated skills impact these health behaviors and related health outcomes (Berkman et al., 2011).

Increasing Rates of Overweight and Obesity

With current dietary and physical activity trends, it is not surprising that the United States has also seen an increase in the prevalence of overweight and obesity, and thus body mass index (BMI), in recent years. The current definition of overweight is having a BMI greater than or equal to 25.0 to 29.9. Similarly, obesity is classified as having a BMI of greater than or equal to 30.0. Obesity can also be divided further into Grade I (BMI 30 - <35), Grade II (BMI 35 - <40), and Grade III (BMI \geq 40) (Flegal et al., 2010). Since 1960, the prevalence of overweight and obesity has been steadily increasing in all age and racial/ethnic groups (Flegal et al., 1998). Between 1980 and 2004, rates of obesity doubled (Khan et al., 2009) and as of 2010, approximately 78 million (35.7%) of U.S. adults were obese (Ogden et al., 2012). Because obesity is so prevalent and is related to health conditions including cardiovascular disease, diabetes, and cancer, the estimated annual medical cost of obesity in 2008 was \$147 billion (Finkelstein et al., 2009).

While rates of overweight and obesity have increased across age and ethnic groups, some groups are more affected than others. Non-Hispanic blacks have the highest rates of obesity (49.5%) followed by Mexican Americans (40.4%), all Hispanics (39.1%), and non-Hispanic whites (34.3%) (Flegal et al., 2012). Additionally, socioeconomic status has been

shown to be related to obesity in certain groups. Among women, higher income is related to a decreased likelihood of obesity while the opposite is true among non-Hispanic black and Mexican American men (*Ogden et al., 2010*). Finally, the prevalence of overweight and obesity has also been shown to vary according to geographic location. Higher prevalence was found in the South (29.4%) and the Midwest (29.5%) while the Northeast (25.3%) and the Western (25.1%) parts of the country reported lower prevalence of obesity. Prevalence also varied by state, with rates ranging from 20.5% (Colorado) to 34.7% (Louisiana) of the state population classified as overweight or obese (*CDC, 2013*). Along with understanding trends in overweight and obesity prevalence, clinical indicators of disease is equally important.

Trends in Clinical Indicators

While overweight and obesity is one of the top risk factors for cardiovascular disease, others also include hypertension, high low-density lipoprotein cholesterol (LDL-C), and high fasting plasma glucose (*CDC, 2011*). All of these risk factors have shown increased prevalence in recent years (*CDC, 2011*). Hypertension is defined as having a systolic blood pressure of ≥ 140 mmHg and/or a diastolic blood pressure of ≥ 90 mmHg (*Egan et al., 2010*). Between 1988-1994 and 1999-2000, rates of hypertension increased from 23.9% to 28.5%, and while rates remained static between 1999-2000 and 2007-2008 (*Egan et al., 2010*), as of 2010, 31% of US adults have been diagnosed with hypertension (*CDC, 2011*). Additionally, approximately 30% of US adults are prehypertensive (systolic blood pressure, 120 – 139 mmHg and/or diastolic blood pressure, 80 – 89 mmHg) (*Roger et al., 2012*) and less than half (47%) of Americans with hypertension have their blood pressure under control (*CDC, 2011*). While incidence varies by age and ethnicity, the major risk factors for hypertension are weight, diet, physical inactivity, and diabetes (*Roger et al., 2012; CDC, 2011*).

Another major risk factor for cardiovascular disease, high LDL-C (≥ 130 mg/dL), or “bad” cholesterol, has maintained a prevalence of approximately 34% for the past decade; however, only one in three people affected by high LDL-C have the condition under control (CDC, 2011). LDL-C is only one component of blood lipids that contributes to an individual’s total cholesterol level, but is most often the driving force behind elevated high total cholesterol levels. Currently, the average total cholesterol level in US adults is 200 mg/dL, which is classified as “borderline high” (Roger *et al.*, 2012). Individuals with high total cholesterol have twice the risk of heart disease and stroke as individuals with optimal levels (< 200 mg/dL) (CDC, 2011).

Diabetes is another chronic illness that affects millions of Americans and is the seventh leading cause of death in the United States (CDC, 2011). Currently affecting 8.3% of the population, diabetes prevalence has increased steadily since 1988-1994 (7.8%) and an additional 1.9 million cases (~1%) were diagnosed in 2010 alone (CDC, 2011). In addition to diagnosed diabetes (fasting plasma glucose ≥ 126 mg/dL) in 2005-2008 approximately 35% of US adults had prediabetes (fasting plasma glucose, 110-125 mg/dL) (CDC, 2011; Harris *et al.*, 1998), which was a considerable increase from the estimated prevalence of prediabetes in 1988-1994 (6.9%) (Harris *et al.*, 1998). Prediabetes also carries an increased risk of heart disease and stroke, but research has shown that some prediabetics are able to return blood glucose levels to normal through diet, physical activity, and weight loss (CDC, 2011; Norris *et al.*, 2005). Further demonstrating the relationship between these cardiovascular risk factors and conditions, in 2005-2008 approximately 67% of diabetics were also diagnosed with hypertension and, in 2001-2002, approximately 64.6% had LDL-C levels of greater than 100 mg/dL (CDC, 2011; Roger *et al.*, 2012).

Due to increased prevalence of each of these individual risk factors, prevalence of metabolic syndrome has also increased in recent years (Ervin, 2009; Park *et al.*, 2003). Metabolic syndrome is the constellation of risk factors that increase an individual’s risk for

developing cardiovascular disease, namely abdominal obesity, elevated triglycerides, low high-density lipoprotein (HDL) cholesterol, elevated blood pressure, and elevated fasting plasma glucose (*National Heart, Lung, and Blood Institutes, 2011*). While the exact prevalence of metabolic syndrome is unknown due to variability in the populations that have been evaluated and slight differences in diagnostic criteria, metabolic syndrome was estimated to affect approximately 22.8% of U.S. men and 22.6% of U.S. women between 1988 and 1994 (*Park et al., 2003*). More recently, research has indicated a rise in the prevalence of metabolic syndrome to approximately 34% of the U.S. population between 2003 and 2006 (*Ervin, 2009*). Metabolic syndrome doubles an individual's risk of developing cardiovascular disease and carries a five-fold risk of developing diabetes; however, while risk of developing metabolic syndrome is related to genetics and age, it can be prevented by decreasing risk of other individual factors through weight loss, diet, and physical activity (*NHLBI, 2011*).

Observations about Health Literacy

Health Literacy and Dietary Behaviors

Recent literature on health literacy has explored the role of health literacy in health care costs, health care services, adherence to medical recommendations, and certain health outcomes (*Berkman et al., 2011; Clement et al., 2009*). Health literacy research has also explored the relationships between health literacy and trust of nutrition information sources (*Zoellner et al., 2009*) and clinical indicators in disease self-management (*Cavanaugh et al., 2009; Rothman et al., 2004*); however, there is very little research available about the role of health literacy in dietary behaviors. Only one recent study has examined the relationship between health literacy and diet quality and one has observed the relationship between health literacy and fruit and vegetable consumption (*Zoellner et al., 2011; von Wagner et al., 2007*).

Using a cross-sectional design, Zoellner and colleagues aimed to evaluate the scope of limited health literacy and the relationships between health literacy and diet quality (Healthy Eating Index [HEI] scores) and SSB intake in the Lower Mississippi Delta region, one of the most health disparate areas in the United States (2011). Researchers collected demographic data, dietary data (food frequency questionnaire), and determined health literacy status through the use of the Newest Vital Sign. Three hundred seventy six observations were included in data analysis. Zoellner and colleagues found that 51.8%, 22.1%, and 26.0% of participants had limited health literacy, the possibility of limited health literacy, and adequate health literacy, respectively. The average HEI score was 52.2 ± 10.5 and respondents with higher health literacy scored approximately four points higher than low health literate respondents. Multiple linear regression models indicated that every additional point in health literacy was associated with 1.2 additional points on HEI scores and a decrease of 34 kcal/d of SSB intake. In addition to highlighting the potential clinical consequences that low health literacy has on diet quality, this study is the first to establish a link between health literacy and diet quality (Zoellner et al., 2011).

Focusing on a specific subset of dietary quality, von Wagner and colleagues aimed to determine the effects of health literacy on fruit and vegetable intake (2007). Demographic data as well as information about smoking status, physical activity behaviors, and fruit and vegetable consumption was collected from 719 British adults. Health literacy was assessed using a modified version of the TOFHLA for British adults. Researchers found that 5.7% of participants were classified as having inadequate health literacy and 5.7% as having marginal health literacy. Additionally, von Wagner and colleagues found that only 29.3% of individuals with inadequate health literacy consumed more than five servings of fruits and vegetables a day, while 39% of those with marginal health literacy and 47% of those with adequate health literacy consumed more than five servings of fruits and vegetables daily, indicating that higher health

literate individuals were more likely to meet the daily recommendation for fruits and vegetables (von Wagner et al., 2007).

Health Literacy and Physical Activity Behaviors

Similarly, very little research has been conducted on the relationship between health literacy and physical activity behaviors. However, it has been suggested that individuals who perceive behavioral factors, such as physical activity, to not be important were more likely to have inadequate health literacy (Adams et al., 2013). There have been two recent studies that have explored the relationship between health literacy and physical activity behaviors (von Wagner et al., 2007; Wolf et al., 2007). Unfortunately, they have provided conflicting conclusions about the existence of such a relationship.

In addition to measuring fruit and vegetable consumption, von Wagner and colleagues also observed the relationship between health literacy and physical activity behaviors in British adults (2007). Using a modified version of the TOFHLA, they found that 11.4% of their study population had inadequate or marginal health literacy, and that there was no relationship between health literacy level and a likelihood of having exercised within the past seven days (von Wagner et al., 2007).

Wolf and colleagues also examined the relationship between health literacy and physical activity behaviors in an adult population (2007). Researchers gathered information on smoking status, seat belt usage, alcohol use, and physical activity from 2,923 participants. Literacy level was assessed through the S-TOFHLA. Wolf and colleagues had a larger percentage of participants with inadequate health literacy (22.2%) and marginal health literacy (11.3%) than von Wagner (2007), and contrary to their results, Wolf and colleagues found that individuals with inadequate health literacy were more likely to live a sedentary lifestyle (physical activity <1 time per week; 38.2% vs. 21.6%, $p < 0.001$) compared to individuals with adequate health literacy

(Wolf et al., 2007). Due to the contrasting evidence available, clearly further research is necessary to determine whether there is a relationship between health literacy and physical activity and if so, the nature of this relationship.

Health Literacy and Body Mass Index

The relationship between health literacy and body mass index (BMI) is yet another association that has received little attention from researchers. Of the research that has been conducted, the results are contradictory. Baker and colleagues observed the relationship between elderly adults and BMI in order to determine whether low health literacy predicted overall and cause-specific mortality (2007). Literacy was measured using the TOFHLA and it was found that of 3,260 participants, 64.2% had adequate health literacy, 11.2% had marginal health literacy, and 24.5% had inadequate health literacy. In this elderly population (mean age, 72.8 years), individuals with inadequate health literacy were more likely to be underweight (BMI <18.5 kg/m²) (Baker et al., 2007).

In a similarly aged population (mean age, 76 years), Sudore and colleagues also observed the relationship between literacy level and BMI (2006). Health literacy was measured by the REALM and it was determined that 8.4% of participants were between a 0-6th grade reading level or had inadequate health literacy, 15.2% of participants were between a 7-8th grade reading level or had marginal health literacy, and 76.3% were at or above a 9th grade reading level, or had adequate health literacy. Contrary to the findings of Baker and colleagues (2007), Sudore and colleagues found that participants with inadequate and marginal health literacy were more likely to be obese (BMI ≥ 30 kg/m²) than participants with adequate health literacy (BMI 0-6th grade, 29.3 kg/m²; 7-8th grade, 32.1 kg/m²; ≥9th grade, 23.0 kg/m²; p < 0.0001) (Sudore et al., 2006).

Rothman and colleagues also noted the relationship between literacy and BMI in a recent study to determine the effects of health literacy and numeracy levels on the ability to correctly interpret nutrition labels (2006). Using the REALM to measure health literacy, 23% of the 200 respondents were determined to have less than a high school reading level while 77% were at or above a high school reading level. In terms of BMI, 53% of participants with inadequate health literacy were considered obese (BMI ≥ 30 kg/m²) while 43% of participants with adequate health literacy were obese; however, while slightly fewer participants with adequate health literacy were considered obese, there was no significant difference between the two groups ($p = 0.31$) (Rothman et al., 2006).

Health Literacy and Clinical Indicators

Unlike other areas of health literacy research, there have been several studies that explore the relationships between health literacy level, hypertension, and type II diabetes, though fewer have focused on the relationship to blood lipids. However, the results of these studies are still mixed, indicating that there is still a need for future research in these areas.

Three studies explored differences in rates of specific chronic diseases by health literacy level in elderly populations. Two used the TOFHLA to measure health literacy (Wolf et al., 2005; Kim, 2009) while one used the REALM (Sudore et al., 2006). All three found that lower health literacy levels were significantly associated with higher rates of hypertension, and two (Wolf et al., 2005; Sudore et al., 2006) found that lower health literacy levels were also associated with increased rates of type II diabetes. Another study by Adeseun and colleagues (2012) aimed to determine the relationship between health literacy and prevalence of chronic disease in a population of newly diagnosed dialysis patients. Using the S-TOFHLA, 20.8% of respondents were found to have low health literacy while 79.2% were found to have adequate health literacy. Researchers found that low health literate individuals had significantly higher diastolic blood pressure and, after adjustment for demographic and socioeconomic variables,

slightly higher systolic blood pressure, though these rates only approached significance (Adeseun *et al.*, 2012). Yet another study by Morris and colleagues (2006) found no significant difference in either systolic or diastolic blood pressure by health literacy level, nor any difference in hemoglobin A_{1c} levels after controlling for demographic characteristics and several factors relevant to chronic disease management.

In addition to the studies already discussed (Morris *et al.*, 2006; Wolf *et al.*, 2005; Sudore *et al.*, 2006), three other medium-sized studies explored the relationship between health literacy and hemoglobin A_{1c} levels (Tang *et al.*, 2007; Powell *et al.*, 2007; Manusco, 2010). Two studies found that higher health literacy was associated with more glycemic control, or lower hemoglobin A_{1c} (Tang *et al.*, 2007; Powell *et al.*, 2007), while Manusco found no differences in hemoglobin A_{1c} by health literacy level (2010). However, all three studies used different instruments to measure health literacy which may have led to differences in cut points and classifications of inadequate or adequate health literacy.

Very little research has focused on the relationship between health literacy level and blood lipids. Only two known studies observed these relationships and while in the smaller study (N = 72) lower health literacy as measured by the S-TOFHLA was associated with higher high-density lipoprotein cholesterol (HDL-C), no significant results were found (Adeseun *et al.*, 2012). Similarly, there was no significant difference in low-density lipoprotein cholesterol (LDL-C) or triglyceride levels in either study (Adeseun *et al.*, 2012; Morris *et al.*, 2006).

Additionally, research regarding the relationship between health literacy and prevalence of metabolic syndrome has been limited to nonexistent. In one recent study, Joshi and colleagues examined current health literacy levels, perceptions about metabolic syndrome, and associated management challenges in an Indian setting (2013). While researchers found that the majority of their population had a very limited knowledge about the risk factors and common

symptoms associated with metabolic syndrome, they did not examine whether rates of metabolic syndrome differed by health literacy status (*Joshi et al., 2013*). Due to the mixed results as to the relationship between health literacy level and hypertension, diabetes, and the lack of research in the area of health literacy and blood lipids and metabolic syndrome, future research is necessary to determine the nature of the relationship between health literacy and these specific clinical markers.

Observations about Health Numeracy

Health Numeracy and Dietary Behaviors

Similar to health literacy research, there have been relatively few observational studies focused on the effects of health numeracy on health behaviors and those that do exist vary greatly in their focus of outcome. To date, there have been no studies that focus primarily on the relationship between health numeracy and diet quality or dietary intake. In one recent study, Rothman and colleagues explored the relationships between health literacy, health numeracy, and the ability to correctly interpret nutrition labels (*2006*). The REALM and the Wide-Range Achievement Test, third edition (WRAT-3) were used to measure health literacy and health numeracy, respectively. Of the 200 participants that completed the study, 77% had a reading level at a higher school level or greater, but only 37% had numeracy skills at the same grade level. Overall, participants answered 69% of the questions about the nutrition label correctly and it was determined that participants were much more likely to make errors if the question required the use of fractions or decimals. The results of this study suggest that while many individuals, even those with higher levels of education, can have difficulty interpreting food labels, performance is highly correlated with literacy and numeracy skills and that individuals with poor literacy and numeracy skills are much more likely to make errors (*Rothman et al., 2006*).

Health Numeracy and Physical Activity Behaviors

As mentioned previously, health numeracy is a relatively new field and very little research has been conducted regarding the effects of health numeracy on various health behaviors and outcomes. Currently, there are no observational studies that aim to determine the relationship between health numeracy and physical activity behaviors. Clearly, this is an area where future research is greatly needed.

Health Numeracy and Body Mass Index

Numeracy skills can also be important in weight management as there are many numerical skills needed to track calories, physical activity, and weight. Huizinga and colleagues recently explored these relationships between numeracy skills and weight status as measured by BMI (2008). The REALM and the WRAT-3 were used to measure health literacy and health numeracy, respectively. Of the 160 participants who completed the study, only 23% had less than 9th grade literacy skills while 66% had less than 9th grade numeracy skills, again demonstrating that inadequate numeracy skills are much more prevalent than inadequate literacy skills. Researchers found that numeracy was negatively correlated with BMI and literacy was not correlated with BMI. Low numeracy was also associated with higher BMI scores when treated as a categorical variable. The mean BMI score for participants with less than 9th grade numeracy skills was 31.8 ± 9.0 kg/m² compared to 27.9 ± 6.0 kg/m² for participants with higher numeracy skills. The results of this study show that individuals with low numeracy skills may have difficulty with weight management and that further research is warranted to better understand the relationship between health numeracy, weight, and other health outcomes (Huizinga et al., 2008).

As mentioned previously, Rothman and colleagues also observed the relationship between numeracy and BMI (2006). Contrary to Huizinga and colleagues (2008), Rothman

found no significant difference in rates of obesity between participants with high health numeracy levels and participants with low health numeracy levels as determined by the WRAT-3 (<HS, 48%; ≥HS, 40%; $p = 0.30$) (Rothman et al., 2006).

Health Numeracy and Clinical Indicators

Cavanaugh and colleagues explored the association between diabetes related numeracy and perceived self-efficacy, self-management of the disease, and clinical measures such as hemoglobin A_{1c} in patients with diabetes (2008). Researchers used the REALM, WRAT-3, and the Diabetes Numeracy Test (DNT) to measure health literacy, general numeracy, and diabetes-related numeracy, respectively. Of the 398 participants who completed the study, 31% had less than 9th grade literacy skills and 69% has less than 9th grade general numeracy skills. Researchers found that patients with lower literacy skills answered 40% of the DNT questions correctly while patients with higher literacy skills answered 74% of the questions correctly. A similar trend was seen with patients of low general numeracy skills: only 51% of questions were answered correctly compared with 83% from patients with adequate numeracy skills. Of particular concern, almost 1 in 4 patients could not correctly determine which blood glucose values were within the normal range and, of patients taking insulin, low diabetes-related numeracy was correlated with less participation in self-management activities. These data suggest that literacy alone may not provide an adequate assessment of patient's numeracy skills and abilities to self-manage specific diseases. Future research should focus on the role of numeracy in health behaviors and how to improve care for patients' with chronic illnesses (Cavanaugh et al., 2008).

The primary focus in the literature on health numeracy and clinical indicators of disease has been on measures for diabetes such as hemoglobin A_{1c}. There have been no observational studies exploring the relationship between health numeracy and hypertension prevalence or

control, the relationship between health numeracy and blood lipids, or the relationship between health numeracy and prevalence of metabolic syndrome. Future research should aim to determine whether a relationship exists between health numeracy and these clinical outcomes.

Reviews and Interventions targeting Health Literacy and Health Numeracy

Health Literacy

In a recent review, Taggart and colleagues evaluated the effectiveness of interventions used in primary care to improve health literacy for change in smoking, nutrition, alcohol, physical activity, and weight (SNAPW) (2012). Fifty-two intervention studies including 29 randomized controlled trials, 14 randomized trials, 6 before and after studies, 2 quasi experimental studies, and a non-randomized controlled trial were evaluated. Each study that was evaluated had to measure at least one outcome associated with health literacy and report a SNAPW behavioral risk factor outcome. The researchers found that group education was the most common intervention (28.8%) and that nutrition (65.4%) and physical activity (61.5%) were the most common SNAPW risk factors targeted. Of all of the intervention types found (written materials, telephone, web-based, group education, individual counseling, and multiple interventions), written materials and multiple interventions were the most effective in changing nutrition whereas all intervention types were equally effective in changing physical activity behaviors. Additionally, researchers found that neither the intensity of the intervention (low, medium, high) nor whether the intervention targeted multiple SNAPW risk factors affected the effectiveness of the intervention (Taggart *et al.*, 2012).

In regards to health literacy, Taggart and colleagues found that 73% of studies reported positive change in health literacy; however, most studies utilized measures of self-efficacy, confidence, or readiness to change rather than health literacy explicitly (2012). In fact, of the 41 interventions described in the review, none use a valid measure of health literacy. Specifically,

the majority of interventions (60%) measured changes in participants' stage of change. Researchers noted that they used a broad definition of health literacy, which led to their inclusion of studies that utilized proxy measures of health literacy, including readiness for change, self-efficacy, and attitudes. While the results of the review should be interpreted carefully, Taggart and colleagues concluded that 1) community settings seemed to be more effective than clinical settings when attempting to develop positive physical activity and nutrition behaviors as well as develop health literacy and 2) that changing nutrition may require the highest health literacy compared to other health behaviors as there is a higher level of knowledge and skills required to change one's eating behaviors. Ultimately, there is a need for more research to determine which interventions are most effective in positively impacting health literacy (*Taggart et al., 2012*).

In another recent review, Clement and colleagues evaluated the literature on the effects of complex interventions intended to improve health-related outcomes of individuals with limited literacy and/or numeracy (*2009*). Researchers defined complex interventions as, "an intervention that comprises a number of separate elements which seem essential to the proper functioning of the intervention although the 'active ingredient' of the intervention that is effective is difficult to specify". Complex interventions can include the use of written materials, pictorial information, and human interaction to improve health behaviors while a simple intervention may employ the use of only one of those strategies. Clement and colleagues reviewed 17 papers reporting 15 trials, of which 11 were randomized controlled trials and 4 were quasi-experimental. Inclusion criteria for the review stated that interventions needed to intend to improve limited literacy or numeracy and that one of the following outcomes must be measured: clinical outcomes, health knowledge, health behaviors, self-reported health status/quality of life, self-efficacy/confidence in relation to health/health behavior, utilization of health care, or health professional behavior. As a result of these criteria, health issues studied included a range of

health outcomes including hypertension, cardiovascular disease, and diabetes self-management; however, only one study directly measured changes in nutrition. Additionally, literacy levels of the study population were only assessed in 11 of the 15 interventions and in each of these studies, different measures of literacy and cut points were used (*Clement et al., 2009*).

In 13 of the 15 studies, statistically significant findings favoring the intervention were reported. Of the outcomes reported, the two most common outcomes to be positively impacted by complex interventions designed to improve literacy were health knowledge and health behavior. However, some interventions may have improved health knowledge or health behavior regardless of the study population's literacy level. The current review focused on literacy and numeracy, but no intervention included numeracy as a primary focus. It is clear that there is still a large gap in the literature about health numeracy and interventions to help improve numeracy skills. Additionally, researchers acknowledged that there are still large gaps in our knowledge of health literacy and that while, theoretically, improving health literacy should improve physical health further research is needed to come to that conclusion (*Clement et al., 2009*).

Berkman and colleagues conducted two systematic reviews to understand the relationships between health literacy and the use of healthcare services, health outcomes, and disparities in health outcomes (*Berkman et al., 2004; Berkman et al., 2011*). In the first, researchers only evaluated print health literacy and health outcomes and found an association between low health literacy and limited health knowledge. There was insufficient evidence to draw conclusions about the relationship between low health literacy and other health outcomes. In the current review, researchers expanded their search to include more recent research and include articles that observed the relationships between health outcomes and print literacy and numeracy in combination, or numeracy alone (*Berkman et al., 2011*).

Ninety-six studies in 111 articles were determined to be of good or fair quality and were reviewed by researchers. All studies were observational and most were cross-sectional in design (91 of 111 articles). However, all studies differed in the instrument used to measure health literacy or health numeracy and all studies had different cut points or levels of health literacy. For example, some included three categories – adequate, marginal, and inadequate health literacy – while others only compared differences between the highest and lowest categories. In order to be included for review, studies had to compare participants to an outcome such as health care access and service use, health outcomes, cost of care, or health knowledge. Unlike previous reviews, outcomes concerning attitudes were not evaluated (*Berkman et al., 2011*).

Researchers observed several relationships between various health outcomes and limited health literacy including an increase in emergency care and hospitalizations and decreased use of preventive services, ability to appropriately take medication, and ability to interpret medication labels and health messages. Additionally, a decrease in global health status and an increase in mortality were seen in elderly populations with limited health literacy. Berkman and colleagues also observed the relationships between health literacy and outcomes such as mental health and severity and symptoms of HIV infection, but found the strength of the evidence to be low. They also judged that there was insufficient evidence due to a lack of research to draw conclusions about health literacy and access to care, health outcomes such as BMI in adults and children, the ability to interpret nutrition labels, hypertension control, diabetes control, and the prevalence of chronic disease. While researchers note that there have been many advances in health literacy research and that many of their concerns that were raised in their first review have been addressed, they acknowledge that there is still much more work to be done, specifically requesting research that would increase the generalizability of results to the greater population (*Berkman et al., 2011*).

Carbone and Zoellner conducted a systematic review to summarize the literature on nutrition and health literacy and to identify gaps in the literature while raising awareness of the importance of health literacy in dietetic practice (2012). An initial 101 articles were identified for review; however, after excluding studies that lacked primary data, did not specify a readability measure or include a valid health literacy measure, did not include outcomes specific to nutrition, or focused on children instead of adults, 33 studies were ultimately identified for further review. The reviewed studies all were published prior to March 2010 and fell within three categories: measurement development studies (n = 4), metrics to assess individual health literacy status and readability assessments (n = 16), and evaluation of readability of nutrition education materials for patients and individual literacy assessments (n = 13) (*Carbone and Zoellner, 2012*).

The four measurement development studies all focused on the testing of new health literacy measures specific to nutrition. They included the Newest Vital Sign by Weiss and colleagues, the Nutritional Literacy Scale by Diamond, the Nutrition Label Survey by Rothman and colleagues, and the Cardiovascular Dietary Education System (CARDES) by TenHave and colleagues. Of the 16 readability studies, 11 focused on print materials and five focused on online materials. Review of these studies found that the average readability of educational materials ranged from a grade level of 1.8 to 15.8 and in seven studies, the mean grade level was found to be a ninth-grade level or above despite the fact that the majority of Americans read at an eighth-grade and 20% read at or below a fifth-grade level. Finally, 13 studies that fell into the evaluation of readability of nutrition education materials and individual literacy assessments category were reviewed. Of these, six were experimental and seven were non-experimental. Each experimental study revised patient educational materials to a lower reading level in order to increase nutrition knowledge, and among these studies the intervention groups consistently had higher nutrition knowledge scores than the control groups. Unfortunately,

because of differences in dose, duration, and control groups across studies, it is difficult to determine the effectiveness of these interventions. Ultimately, Carbone and Zoellner called for the education of dietetics practitioners on the use of readability assessments in order to bring patient materials to a more appropriate level and increase the quality of care, as well as developing experimental interventions aimed at low health literacy as there is still a great need for more high-quality health literacy studies (*Carbone and Zoellner, 2012*).

Another systematic review conducted by Allen and colleagues aimed to present the findings of a RE-AIM review in order to determine the degree to which health literacy interventions targeting health promotion and disease self-management reported on internal and external validity (*2011*). Articles that were chosen for review were published between 2000 and February 2010, were experimental or quasi-experimental, and assessed literacy, health literacy, or numeracy among participants. Ultimately, 31 articles describing 25 trials (14 experimental, 11 quasi-experimental) met inclusion criteria and were reviewed. Of these trials, only two ensured that participants had a low health literacy status by use of specific inclusion criteria, and only 38% of participants across all included trials had low health literacy. Only two trials explored changes in health literacy as a result of an intervention and both observed increases in health literacy, providing evidence against the controversial theory that health literacy is a static measure. Additionally, eight studies performed moderation analysis by health literacy level. Four found no moderation effects, three found mixed effects, and only one found that their intervention was more successful in low health literate than high health literate individuals. Finally, only one study of 25 recruited participants in a community setting, further reinforcing the need for health literacy research to branch out from clinical and primary care settings to community settings. Similar to other recent systematic reviews of health literacy interventions, Allen and colleagues found that there were considerable gaps in the literature regarding the effectiveness of health literacy trials (*Allen et al., 2011*).

These reviews of the health literacy research show that previous studies have primarily focused on clinical outcomes in primary care settings (*Berkman et al., 2011; Allen et al., 2011*). However, previous research has also determined that lower health literate populations may have less access to primary care (*Berkman et al., 2011*). Therefore, future health literacy research should focus on community-based settings. Additionally, while all five systematic reviews had different aims, all ultimately came to the same conclusion: that there are still large gaps in health literacy research and that further research is warranted to determine the relationships between health literacy and health promoting behaviors such as nutrition and physical activity, and to identify effective interventions to improve health literacy, physical health, and eliminate health disparities. Very few studies evaluated in these reviews focused on the effects of health literacy on physical activity or dietary behaviors, which clearly indicates the need for health literacy research as it relates to nutrition and physical activity.

Health Numeracy

Health literacy research has grown significantly in recent years as improving health literacy has been prioritized by the United States Department of Health and Human Services and by various professional associations, including the Academy of Nutrition and Dietetics; however, health numeracy and its effects on health behaviors and health outcomes has received much less attention until very recently. Therefore, there is relatively little research describing the effects of health numeracy on various health outcomes and even less that explores the relationships between health numeracy and health promoting behaviors such as nutrition and physical activity.

In a recent review, Reyna and colleagues explored how numeracy influences risk comprehension and medical decision making (*2009*). Researchers found that much of the research exploring the relationship between numeracy and risk perception was related to breast

cancer, or other cancers, and there was variation in the use of instrument to measure numeracy. Overall, it was found that participants with lower numeracy skills consistently overestimate their risk of cancer and other health risks, are less able to use risk reduction information, and may overestimate the benefits of treatment options when compared to participants with higher numeracy skills. Again, researchers noted that there is a considerable gap in the research when it comes to relationships between health numeracy and health outcomes and behaviors (*Reyna et al., 2009*).

Two previously mentioned reviews on health literacy (*Berkman et al., 2011; Clement et al., 2009*) also made attempts to evaluate the current research on numeracy. Berkman and colleagues reviewed 22 studies that evaluated outcomes including health disparities, the use of health services, and health. Three outcomes including asthma control, diabetes self-management, and the ability to interpret food labels and other health information were judged as low evidence indicating that there is a need for more research in these areas. All other outcomes were judged as insufficient, meaning that findings from these studies were either inconsistent or were only supported by one unadjusted analysis. These outcomes included accuracy of risk perception, knowledge, skills in taking medication, self-management behavior, and disease severity and prevalence (*Berkman et al., 2011*). Of the trials that Clement and colleagues reviewed, all focused on health literacy rather than health numeracy, again indicating a clear need for future research in this area (*Clement et al., 2009*).

Recent interventions targeting numeracy and health outcomes have suggested an association between health numeracy and anticoagulation control (*Estrada et al., 2004*) and hospitalizations in patients with asthma (*Apter et al., 2006*). However, relatively few have focused on nutrition-related outcomes and none known have targeted physical activity behaviors.

In a recent study, Visschers and colleagues aimed to determine if numeracy skills played a role in the differentiation between regular-fat and reduced-fat food products (2010). Researchers used the Subjective Numeracy Scale (SNS) to measure numeracy and instructed participants to choose which product, if either, they would buy for themselves based on the fat content of the product (chips and yogurt). Fat reduction did influence the decisions of participants with higher numeracy levels, but those with lower numeracy levels did not seem to differentiate between the products (i.e. low numeracy individuals chose product A through each of the choices even when products B or C had differing fat content), indicating that when there are not clear cues as to which product may be healthier, consumers with low numeracy skills may make other food choices which could be unhealthier (*Visschers et al., 2010*). While there is still a need for future research to determine the relationships between health numeracy, nutrition, and physical activity, this study does provide further insight into the relationship between numeracy and the ability to interpret nutrition labels and make healthy food choices.

Conclusion

Based on the literature reviewed, the majority of health literacy and numeracy research focuses heavily on the role that health literacy and numeracy play in perception of disease risk, health care costs, all-cause mortality, and access to care (*Berkman et al., 2004; Berkman et al., 2011; Reyna et al., 2009*); however, very little research has been conducted on the relationships between health literacy and numeracy and health promoting behaviors including diet and physical activity, or disease prevalence and control. What little research that has been conducted recently has yielded mixed results. There is a clear gap in the literature regarding cross-sectional relationships between health literacy and dietary intake or quality, physical activity, and body mass index, and an even wider gap in the literature regarding health numeracy and these behaviors. Future research should focus on determining whether such

relationships exist in order to best guide future practice in addressing dietary intake, including SSB consumption, physical inactivity, and chronic disease prevention.

Aims and Hypotheses

In order to help bridge the gap in health literacy and health numeracy research, the primary aims of this research are to:

1. Examine correlations among health literacy and numeracy measures, namely the Newest Vital Sign (NVS), separated by reading (NVS Reading) and math (NVS Math) scores, the Rapid Estimate of Adult Literacy in Medicine (REALM), and the Subjective Numeracy Scale (SNS);
2. Explore the relationships between demographic factors including age, gender, race, education, and income and the NVS, REALM, and SNS;
3. Determine the relationships between the NVS, REALM, and SNS and anthropometric/biological variables (body mass index, blood pressure, fasting blood glucose, and fasting blood lipids), physical activity behaviors, and dietary quality (i.e. HEI scores); and
4. Determine if NVS, REALM, and SNS scores predict metabolic syndrome, while controlling for relevant demographic factors.

We hypothesize that 1) NVS Reading scores will be significantly positively correlated with REALM scores and NVS Math scores will be significantly positively correlated with SNS scores; 2) age will be significantly negatively associated with the NVS, REALM, and SNS, gender will be significantly associated with the SNS, race will be significantly associated with the NVS, REALM, and SNS, and education and income will be significantly positively associated with the NVS, REALM, and SNS; 3) BMI, blood pressure, fasting blood glucose, total cholesterol, LDL cholesterol, and triglycerides will be significantly negatively associated with health literacy and numeracy measures (i.e., NVS, REALM, and SNS) while HDL cholesterol, physical activity behaviors and dietary quality will be significantly positively associated with health literacy and numeracy measures; and 4) health literacy (i.e., NVS and REALM) and

health numeracy (i.e., SNS) will be inversely predictive of metabolic syndrome, while controlling for relevant demographic factors.

Chapter 2

Exploring Cross-Sectional Relationships between Health Literacy, Dietary Intake, Physical Activity, and Anthropometric/Biological Variables among Residents from Southwest Virginia

Introduction

Low health literacy and numeracy are significant problems affecting the United States and have been associated with poorer health outcomes, increased health costs, increased hospitalizations, decreased use of preventive care, and higher health costs (*Berkman et al., 2004; Berkman et al., 2011*). While there is a link between literacy and numeracy, poor quantitative skills are still prevalent in individuals with high literacy, and in some cases health numeracy and not literacy is associated with poorer health outcomes (*Cavanaugh et al., 2008; Huizinga et al., 2008; Osborn et al., 2013*). As our nation's health continues to decline with obesity and other chronic diseases becoming more prevalent, it is important to understand the role that health literacy and health numeracy play in health promoting behaviors, such as nutrition and physical activity, and in the prevalence and control of chronic disease.

Health literacy research has grown considerably in recent years, but there is still very little research on the relationship between health literacy level and diet or physical activity. While there is a larger body of literature surrounding the relationship between health literacy and chronic disease prevalence, what evidence does exist has produced a picture of an unclear relationship and has been judged as insufficient by two large reviews (*Berkman et al., 2004; Berkman et al., 2011*). There is an even larger gap in health numeracy research, as health numeracy has only recently been identified as a separate, valuable entity from health literacy. Only a handful of recent studies have addressed the relationship between health numeracy and health outcomes, and no known observational studies have focused on the relationships between health numeracy and diet quality, dietary intake, physical activity, or chronic diseases such as hypertension or hypercholesterolemia, despite the fact that numeracy has been

identified as an important skill in tracking daily calories or steps, accurately interpreting nutrition labels, and diabetes self-management (*Huizinga et al., 2008; Rothman et al., 2006; Cavanaugh et al., 2008*).

Certain subpopulations have been found to suffer disproportionately from limited health literacy including those living below the poverty line, those with fewer completed years of education, the elderly, and those that do not speak English as their first language. Incidentally, rural populations tend to be older, less educated, and make less money than urban populations and, in fact, rural populations have been shown to have a higher proportion of individuals with limited health literacy (*Zahnd et al., 2009; Zoellner et al., 2009*). Despite this, there have been no known studies that observe the role of health literacy and numeracy in rural populations on preventive health behaviors, including nutrition or physical activity, or prevalence of chronic disease.

In order to best understand and address the health problems that the United States is currently facing, it is essential that research determine the relationships between health literacy, health numeracy, health promoting behaviors including dietary quality and physical activity, and disease prevalence. Only then will researchers be able to develop appropriate interventions to intervene on existing detrimental health behaviors, such as high sugar-sweetened beverage consumption and physical inactivity, and promote chronic disease control and prevention.

This research is embedded within a larger randomized-control trial, Talking Health, which is a six-month, two-arm trial targeting residents in eight counties in southwest Virginia to determine the effectiveness of a behavioral intervention to reduce SSB consumption. The primary aims of this research are to 1) examine the correlations between health literacy and health numeracy measures (NVS, REALM, and SNS), to 2) explore the relationships between demographic factors and health literacy and numeracy measures, to 3) determine the

relationships between the NVS, REALM, and SNS and anthropometric and biological variables including BMI, blood pressure, fasting blood glucose, and fasting blood lipids, physical activity behaviors, and dietary quality (i.e. HEI scores), and to 4) determine if health literacy and numeracy measures are predictive of metabolic syndrome, while controlling for relevant demographic factors.

Methods

Study Design

While this research is a part of a larger six-month, two-arm, matched-contact randomized controlled trial, the current research utilized a cross-sectional design. In the larger parent trial, eligible participants were randomly assigned to a behavioral trial aimed at either decreasing sugar-sweetened beverage (SSB) intake (SipSmartER) or increasing physical activity (Move More). Data collection points were scheduled at baseline, six-month follow-up (immediately following the intervention), and 18-month follow-up (one year post intervention). In order to compensate participants for their time, gift cards in the amounts of \$25, \$50, and \$75 were given at the baseline, six-month, and 18-month data collections, respectively. The present research utilized data collected at the baseline health assessment.

Both groups participated in three small group classes and received one teach back call, and 11 automated IVR (interactive voice response) calls throughout the six-month intervention. Following the six-month data collection, participants were further randomized to a maintenance condition. Maintenance calls were received monthly for 12 months prior to the 18-month data collection (12-month post intervention). The Institutional Review Board (IRB) at Virginia Tech approved this study and all participants gave written informed consent prior to participation in this study.

Target Population

The Talking Health trial targets residents of eight counties in rural southwest Virginia, including Lee, Giles, Pulaski, Washington, Grayson, Wise, Dickenson, Smyth, Tazewell, Bland, Carroll, Patrick, Wythe, and Montgomery counties. The vast majority of residents in these areas are Caucasian (94.6%) and the average annual income is \$49, 206, with 17.5% of individuals living below the poverty line, which is higher than the national average (14.3%). The average educational attainment is also low with 57.6% of residents having received a high school diploma or less (*U.S. Census Bureau, 2013*).

Recruitment and Eligibility

Several recruitment strategies were used to target low socioeconomic, low-health literate residents in each county. In all counties, flyers, newspaper and radio advertisements, and word of mouth were used to recruit participants. Targeted postcard mailings were also used in several counties. Additionally, in several counties, Virginia Cooperative Extension agents were hired to help recruit in their communities and research assistants helped actively recruit participants at several locations including, but not limited to local public libraries, local community colleges, festivals, free health clinics, childcare centers, and government agencies. A rolling enrollment approach was utilized, meaning that additional cohorts were recruited and enrolled in the study while the intervention for earlier cohorts was ongoing.

Inclusion criteria included English speaking adults aged 18 years or older, who consume more than 200 Calories from SSB per day, have no contraindications for moderate-intensity exercise, and have reliable access to a telephone. Additionally, only one member per household was eligible for the study in order to reduce potential confounds. A screening questionnaire was used to determine eligibility and included questions concerning SSB consumption, physical activity behaviors, physical activity limitations, health literacy, and

demographics. Screening took place either via telephone or in person. In Lee, Giles, and Pulaski counties, if participants were eligible based on the screening questionnaire responses and verbally agreed to participate in the study, they were scheduled for a baseline assessment appointment. In later counties (Washington, Grayson, Wise, Wythe, and Montgomery), eligible participants were sent an information packet in the mail detailing the intervention. Approximately one week after receiving the packet, participants received a follow-up phone call to determine whether they were interested in participating in the study, if so, they were then scheduled for a baseline assessment appointment.

Data Collection and Outcome Measures

A data collection manual of procedures was developed and all research staff were trained prior to data collection in order to ensure standardization and consistency of data collection procedures. The baseline assessment consisted of two 30-45 minute appointments. The assessment included computer-administered questionnaires, interview-administered questionnaires, and anthropometric and biological assessments.

The computer-administered questionnaires were specifically developed for this study and included seven previously validated instruments including the BEVQ-15, a 15-item questionnaire that assessed how often and how much SSBs are consumed on average (*Hedrick et al., 2012*); the L-CAT, a 1-item physical activity questionnaire that asked participants to select one of six statements that best describes their average physical activity (*Kiernan et al., 2013*); the SNS, an 8-item questionnaire that assessed an individual's perceived numeracy skills and preference for how numerical information is presented (*Fagerlin et al., 2007; Zikmund-Fisher et al., 2007*); and questions regarding health-related quality of life (4 items) (*CDC, 2011*).

Interviewer-administered questionnaires included the NVS (*Weiss et al., 2005*) and REALM (*Murphy et al., 1993*) to assess health literacy, one 24-hour dietary recall to assess

dietary intake, and the Godin Leisure Time Exercise Questionnaire (*Godin & Shephard, 1985*) to assess physical activity behaviors over the past seven days. The NVS and REALM are both validated, reliable health literacy measures. According to NVS scoring protocol, a score of 0-1 indicated a higher probability of limited health literacy, a score of 2-3 indicated a possibility of limited health literacy, and a scores of 4-6 indicated adequate health literacy (*Weiss et al., 2005*). The REALM was also scored according to protocol. A score of 0-18 indicates a reading level at or below 3rd grade, a score of 19-44 indicates a reading level between 4th and 6th grade, a score of 45-60 indicates a reading level between 7th and 8th grade, and a score of 61-66 indicates a reading level at or above 9th grade (*Murphy et al., 1993*). Subsequent to the one 24-hour dietary recall collected during baseline enrollment, research assistants conducted two more 24-hour dietary recalls via telephone in the two weeks following the assessment appointment. Two week days and one weekend day were collected in order to gain an accurate assessment of participants' diets. All recalls used the multiple pass method and were nonconsecutive (*Stote et al., 2011*).

Nutrition Data System for Research (NDS-R) nutrition analysis software was used to analyze the 24-hour dietary recalls. Recall data was used to calculate HEI scores. Scores consist of twelve dietary components including total fruit, whole fruit, total vegetable, dark green and orange vegetable and legumes, total grains, whole grains, milk, meat and beans, oils, saturated fat, sodium, and calories from solid fats, alcoholic beverages, and added sugars. Individual scores for each component were assigned and summed to determine overall HEI score. Scores range from 0-100 with higher scores indicating higher overall diet quality as determined by the US dietary guidelines (*Guenther et al, 2008*).

Standardized procedures were used to assess BMI, blood pressure, and fasting glucose and blood lipids (total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides). A calibrated digital Tanita scale and portable stadiometer were used to measure participants'

height and weight, without shoes and in light clothing. Fasting blood samples were obtained via finger stick blood sample. Samples were analyzed on-site using CardioChek® equipment. Blood pressure was always measured prior to finger stick using an Omron digital blood pressure monitor. Measurements were taken twice in a span of two minutes from a sitting position and the average blood pressure measurement was reported. Participants with a blood pressure higher than 160/100 mmHg were required to sit quietly for five minutes before additional blood pressure measurement was taken. Participants with readings higher than 180/110 mmHg were required to get physician approval before participating in the intervention.

Metabolic syndrome scores were determined based on current National Cholesterol Education Program (NCEP) guidelines. The current NCEP criteria for metabolic syndrome is the presence of at least three of the following: waist circumference of >40 inches for men or >35 inches for women, triglycerides ≥ 150 mg/dL, HDL cholesterol <40 mg/dL for men or <50 mg/dL for women, blood pressure ≥ 130 mmHg and/or ≥ 85 mmHg, and fasting plasma glucose 110-125 mg/dL. In lieu of waist circumference, obesity was determined by a BMI ≥ 30 kg/m² (*Case et al., 2002; Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001*).

Data Analysis

Data was analyzed using SPSS version 21.0. All data was coded according to validated and standardized coding procedure. Quality assurance checking included examining variable ranges for data entry errors and missing data. All data was double-checked for entry accuracy. Descriptive statistics including means, standard deviations, and frequencies was used to summarize the data. Simple correlations (Pearson bivariate) were used to identify significant correlations between health literacy and numeracy measures. ANOVA tests were used to explore relationships among demographic variables and health literacy and numeracy measures as well as relationships among anthropometric and biological variables, physical activity

behaviors, and dietary quality and health literacy and numeracy measures. Multiple linear regression models were used to determine relationships between the NVS, REALM, and SNS and metabolic syndrome, while controlling for relevant demographic factors.

Results

Participants

Of the 264 participants enrolled, the majority were female (81.8%) and Caucasian (92.0%) with a mean age of 41.1 ± 13.5 years (**Table 1**). Educational status indicated that 30.6% of participants completed less than or equal to a high school diploma as their highest level of education (9.8% <high school diploma, 20.8% high school diploma), while 37.1% completed some college and 32.2% completed college and/or graduate school. Income status indicated that 42% of participants make less than \$15,000 per year before taxes and 28.8% make between \$15,000 and \$29,999 per year. According to NVS scoring protocol, 14.4% of participants were categorized as having a high probability of low health literacy, 19.3% as having a possibility of limited health literacy, and 66.3% as having adequate health literacy. According to REALM scoring protocol, 19.7% of participants were classified as having less than 9th grade reading skills (1.5% \leq 3rd grade, 3.4% 4th-6th grade, 14.8% 7th-8th grade) and 80.3% as having greater than or equal to 9th grade reading skills. For analytical purposes, these categories were collapsed to those with less than 9th grade reading level and those at or above a 9th grade reading level. In terms of health numeracy, 45.4% were classified as having low health numeracy while 54.6% were classified as having high health numeracy, as determined by the SNS. Finally, 29.0% of participants were determined to meet the criteria for metabolic syndrome.

Correlation of Health Literacy and Numeracy Measures

Correlations among health literacy measures (i.e., NVS and REALM) and health numeracy measure (i.e., SNS). Results are illustrated in **Table 2**. Nine of the ten correlations were statistically significant ($p < .01$, two-tailed). The NVS Total was significantly strongly correlated with both the NVS Reading and the NVS Math ($r = .754$ and $r = .925$, respectively; $p < .01$) and significantly moderately correlated with the REALM ($r = .472$, $p < .01$) and the SNS ($r = .283$, $p < .01$). The NVS Reading was also significantly moderately correlated with the NVS Math ($r = .456$, $p < .01$) and the REALM ($r = .329$, $p < .01$), though not significantly correlated with the SNS ($r = .016$). The NVS Math was significantly moderately correlated with the REALM ($r = .452$, $p < .01$) and the SNS ($r = .384$, $p < .01$). Additionally, the SNS was shown to be significantly weakly correlated with the REALM ($r = .189$, $p < .01$).

Differences in Health Literacy and Numeracy Status by Demographic Characteristics

Differences in health literacy scores (i.e., NVS and REALM) and health numeracy scores (i.e., SNS) were examined by demographic characteristics, as illustrated in **Table 3**. Of the three health literacy and numeracy instruments, only NVS scores were found to be significantly different by age ($F = 2.36$, $p = .05$). By gender, only SNS scores were significantly different, with women scoring lower (i.e., having a greater preference for words) than men [Men 4.77 (SD = 1.30); women 4.04 (SD = 1.29) ($F = 12.40$, $p = .001$)].

Health literacy scores (i.e., NVS and REALM), but not numeracy scores (i.e., SNS) were statistically different by race, with Caucasians scoring higher than other races on both instruments [NVS: Caucasian 4.04 (SD = 1.93) questions answered correctly; other race 3.09 (SD = 2.23) questions answered correctly ($F = 4.49$, $p = .03$); REALM: Caucasian 61.82 (SD = 8.89) words pronounced correctly; other race 57.67 (SD = 15.23) words pronounced correctly ($F = 3.74$, $p = .05$)].

All health literacy and numeracy scores were significantly different by education level [NVS ($F = 20.97$, $p < .001$); REALM ($F = 21.06$, $p < .001$); SNS ($F = 11.01$, $p < .001$)]. Among all measures, there is a clear trend of higher scores with increased educational attainment. Post hoc Tukey tests for each health literacy and numeracy measure indicated significant differences between education levels and are represented in the footnotes of **Table 3**. Among all three health literacy and numeracy measures, significant differences in literacy and numeracy levels were primarily found between individuals with less than a high school degree and individuals that had completed either some college or a college degree. While all scores were lower among those only completing some college compared to those completing a college degree or beyond, there were no significant differences in health literacy or health numeracy levels between those groups.

All health literacy and numeracy scores were significantly different by income [NVS ($F = 13.88$, $p < .001$); REALM ($F = 6.80$, $p < .001$); SNS ($F = 14.45$, $p < .001$)]. As with education, there is a clear trend of increasing health literacy and numeracy scores with increased income. Post hoc Tukey tests for each health literacy and numeracy measure revealed significant differences in scores between income levels and are represented in the footnotes of **Table 3**. All health literacy and numeracy scores were significantly lower among those making less than \$15,000 per year when compared to all other income levels. Additionally, SNS scores were also significantly lower among those making \$15,000 to \$29,999 per year when compared to those making \geq \$55,000 per year.

Differences in Anthropometric/Biological Variables, Physical Activity Behaviors, and Diet Quality by Health Literacy and Numeracy Status

Differences in anthropometric and biological variables (i.e., BMI, blood pressure, fasting plasma glucose, and fasting plasma lipids), physical activity behaviors, and diet quality (i.e., average daily SSB intake and HEI scores) by health literacy level (i.e., NVS and REALM) and

numeracy level (i.e., SNS) are illustrated in **Tables 4-7**. As indicated in **Table 4**, there were no significant differences in BMI or fasting plasma glucose by health literacy level or numeracy level. Systolic blood pressure was significantly different by health literacy level as determined by NVS ($F = 3.39, p = .04$). A post hoc Tukey test indicated that systolic blood pressure was significantly higher among those with low health literacy (LHL) compared to those with high health literacy (HHL), as determined by the NVS [LHL 127.9 mmHg (SD = 17.8 mmHg); HHL 120.8 mmHg (SD = 16.1 mmHg) ($p = .04$)]. Systolic blood pressure was also found to be significantly higher among those with high health numeracy as determined by the SNS ($F = 4.55, p = .03$). Diastolic blood pressure was significantly different by health literacy level as determined by the REALM; diastolic blood pressure was significantly higher among those with lower health literacy [$< 9^{\text{th}}$ grade 76.4 mmHg (SD = 10.5 mmHg); $\geq 9^{\text{th}}$ grade 80.5 mmHg (SD = 11.2 mmHg) ($F = 5.79, p = .02$)].

Further analysis showed that 58 (22%) participants used blood pressure medication. However, multiple linear regression models indicated that health literacy [NVS systolic ($R^2 = 0.16, p = .46$); NVS diastolic ($R^2 = 0.06, p = .73$); REALM systolic ($R^2 = 0.16, p = .38$); REALM diastolic ($R^2 = 0.06, p = .31$)] and numeracy [SNS systolic ($R^2 = 0.15, p = .27$); SNS diastolic ($R^2 = 0.06, p = .41$)] were not predictive of either systolic or diastolic blood pressure while controlling for medication usage and demographic variables including age, gender, race, education, and income.

Table 5 illustrates differences in blood lipids (i.e., total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides). No significant differences in blood lipids were found by either health literacy level, as determined by the NVS and REALM, or by healthy numeracy level, as determined by the SNS. There was a trend for higher total cholesterol among those with high health numeracy ($F = 3.32, p = .08$).

Table 6 illustrates differences in vigorous/strenuous activity, vigorous/strenuous and moderate activity, moderate activity alone, and strength training activity as measured by the Godin Leisure Time Physical Activity Questionnaire. There were no significant differences in vigorous/strenuous activity, vigorous/strenuous and moderate activity, or moderate activity alone by health literacy or health numeracy level. Strength training activity was significantly different by health literacy level, as measured by the NVS ($F = 5.46, p = .01$) and the REALM ($F = 3.40, p = .02$). Multiple linear regression models indicated that while health literacy as measured by the REALM was not predictive of strength training activity while controlling for age, gender, race, education, and income ($R^2 = 0.06, p = .92$), health literacy as measured by the NVS was predictive of strength training activity ($R^2 = 0.09, p = .01$); for every one standard deviation increase in NVS score, there was a 0.19 standard deviation decrease in strength training activity, while controlling for demographic variables.

Table 7 illustrates differences in average daily SSB intake (kcal) and HEI scores. As indicated, there were no significant differences in either by health literacy or numeracy level.

Metabolic Syndrome

Table 8 summarizes the results of the multiple regression analysis of the relationship between health literacy, health numeracy and metabolic syndrome. Health literacy, as measured by the NVS and REALM, and health numeracy, as measured by the SNS, were not predictive of metabolic syndrome while controlling for age, gender, race, education, and income.

Discussion

This is one of few known studies to examine the relationships between health literacy, health numeracy, diet quality, and physical activity behaviors. Only one study has previously focused on the relationship between health literacy and diet quality (*Zoellner et al., 2011*), only three recent studies have focused on health literacy and physical activity behaviors (*Adams et*

al., 2013; von Wagner et al., 2007; Wolf et al., 2007), and there have been no known studies that focus on the relationships between health numeracy and diet or physical activity. While there is a larger body of literature surrounding the relationships between health literacy and numeracy and anthropometric/biological variables, including BMI, blood pressure, blood glucose, and blood lipids, there have been no known studies that investigate the relationships between health literacy, health numeracy, and chronic disease prevalence in rural populations. The current research adds to the body of health literacy and health numeracy research by investigating the relationships between health literacy, health numeracy, anthropometric/biological variables, physical activity, and diet quality in a rural population.

Our results indicate that the health literacy instruments (i.e., NVS and REALM) and health numeracy instrument (i.e., SNS) are significantly correlated, which supports our hypothesis that NVS Reading and REALM scores would be significantly positively correlated and that NVS Math and SNS scores would be significantly positively correlated. The only correlation that was not significant was between the SNS and the NVS Reading scores, indicating that these two instruments are measuring different constructs. While an ultimate goal of health literacy research is finding or developing a comprehensive instrument to measure health literacy, that instrument has yet to be found. These results support previous research in that while there is some overlap between the instruments, the relationships are moderate. There is enough of a difference between the constructs measured in each instrument that each can stand alone or be used in conjunction to appropriately measure health literacy and numeracy.

Our findings regarding differences in health literacy and health numeracy status by demographic variables partially support our hypothesis. Health literacy, as measured by the NVS, was found to significantly differ by age, race, education level, and income as hypothesized; however, contrary to our hypothesis, REALM scores did not differ by age. Similarly, health numeracy scores (i.e., SNS) were found to differ by gender, education level,

and income as hypothesized, but not by age or race. These findings generally support previous research as there is ample evidence that health literacy level is influenced by education and income (*Paasche-Orlow et al., 2005; Baker et al., 2007; Sudore et al., 2006; Berkman et al., 2011*). In fact, these two demographic variables are often used as proxies for health literacy level (*Taggart et al., 2012*).

While it was expected that older individuals would have lower health literacy scores, as measured by the NVS and REALM, and lower health numeracy scores, as measured by the SNS, it could be that older individuals had higher levels of education which could likely lead to higher health literacy and numeracy scores. Additionally, the lack of differences between health numeracy scores could be due to the small sample of non-white individuals in the study ($n = 21$) compared to white participants ($n = 243$), or to the absence of a relationship between race and health numeracy.

Our analysis of anthropometric/biological variables, physical activity behaviors, and diet quality by health literacy and health numeracy level revealed interesting results. Contrary to our hypothesis, only systolic blood pressure was significantly different by health literacy level (i.e., NVS) and health numeracy level (i.e., SNS), diastolic blood pressure was significantly different by health literacy level (i.e., REALM), and only strength training activity was significantly different by health literacy level (i.e., NVS and REALM). Many of these relationships were in the opposite direction than hypothesized; systolic blood pressure was higher among those with high numeracy skills and diastolic blood pressure and strength training activity were higher among those with low literacy skills. However, when controlling for hypertension medication use and/or demographic variables, most of these relationships were no longer significant. While possible explanations for the relationship between health literacy (i.e., NVS) and strength training activity are only speculative, it could be due to unmeasured variables such as occupation.

While findings were not statistically significant, it is clear that this population does not meet the recommendations for several cardiovascular disease risk factors. Consistent with national data, average body mass index scores far exceed normal weight categories (*Flegal et al., 1998; Ogden et al., 2012*). Similarly, physical activity levels do not meet the recommended guidelines of 150 minutes of moderate activity per week or 75 minutes of vigorous activity per week (*CDC, 2014*) and sugar-sweetened beverage intake far exceeds the recommendation of no more than eight ounces per day (*Kit et al., 2013*) at all levels of health literacy and health numeracy. Unexpectedly, blood pressure, blood glucose, and blood lipids all meet normal levels despite prevalence of obesity, lack of physical activity, and poor diet quality.

No relationship between health literacy, health numeracy, and diet quality was found; however, it is important to note that dietary quality, as measured by HEI scores, was classified as “poor” (score > 51) (*Ervin, 2008*) across all health literacy and numeracy levels. There are several possible explanations for a lack of a relationship between health literacy and/or numeracy and diet quality. Perhaps there was not enough variation in the sample population due to the eligibility criteria for the parent trial (i.e., ≤ 200 kcal SSB per day). One of the subcomponents of HEI scores is calculated based on Calories consumed from solid fats, alcohol, and added sugars (SoFAAS). Because SSB consumption is so high among all health literacy and numeracy levels due to eligibility criteria, SoFAAS sub-scores could have negatively influenced overall HEI scores. Another possible explanation may involve access to healthy foods. In order to determine whether the food environment plays an instrumental role in individuals’ diet quality independent of health literacy and/or numeracy, additional research would be needed. Future research could also expand HEI scores into individual subcomponents to examine whether differences by health literacy and numeracy lie within subcomponents.

Finally, contrary to our hypothesis, health literacy and health numeracy were not found to predict metabolic syndrome while controlling for age, gender, race, education, and income.

Metabolic syndrome is diagnosed based on the presence three of the following: obesity, elevated blood pressure, elevated blood glucose, elevated triglycerides, and/or low HDL cholesterol. Since this is the first known study to examine relationships among health literacy and health numeracy with metabolic syndrome, future research in this area is warranted.

In previous health literacy studies, the proportion of individuals with low health literacy has ranged from 5.7% to 51.8%, though primarily lying between 20% and 35% (*Zoellner et al., 2011; von Wagner et al., 2007; Adams et al., 2013; Wolf et al., 2007; Baker et al., 2007; Sudore et al., 2006; Rothman et al., 2006; Adeseun et al, 2012; Morris et al., 2006; Wolf et al., 2005; Kim et al, 2009; Tang et al., 2007; Powell et al., 2007; Manusco, 2010; Allen et al., 2012*). The proportion of individuals with low health literacy in our sample is similar to that of previous research; 33.7% of participants in our sample were classified as having a high likelihood of low health literacy or a possibility of low health literacy, as measured by the NVS, and 19.7% of participants were classified as having low health literacy as measured by the REALM. In previous health numeracy studies, the proportion of individuals with low health numeracy has ranged from 48% to 69% (*Rothman et al., 2006; Cavanaugh et al, 2008; Huizinga et al., 2008*). Again, our sample shows similar results with 45.4% having low health numeracy skills as measured by the SNS. However, while our analysis shows similar prevalence of low health literacy and numeracy as previous research, it is difficult to compare our results to other studies due to limitations of available health literacy and numeracy instruments. There are many different instruments available to measure health literacy and each instrument has different categories and cut-points for low health literacy and health numeracy. Additionally, researchers may collapse categories of health literacy differently, further complicating the ability to compare results across studies. This further illustrates the need for a standard, comprehensive health literacy instrument.

One other limitation of this research is that participants are required to have reliable access to a telephone to be eligible to participate in the parent trial. This inclusion criteria could limit the representativeness of our sample by excluding those that live in the most rural areas of southwest Virginia. Additionally, equal variances were assumed for post hoc analysis. Based on the distribution, future research should reexamine post hoc analysis using rank sum tests. Finally, this research utilizes a cross-sectional design and, therefore, causation cannot be determined.

In conclusion, our research suggest that anthropometric/biological variables, physical activity behaviors, and diet quality do not vary by health literacy or numeracy level in rural populations, with the exception of systolic blood pressure, diastolic blood pressure, and strength training activities. These study findings help to fill an important gap in the health literacy and health numeracy literature because it is important that researchers and practitioners understand whether there are relationships, or the extent of the relationships, between health literacy, numeracy, chronic disease prevalence, and health promoting behaviors among different populations. Additionally, this research uncovers other areas of research that are needed to fill gaps in the health literacy research. Future research from the parent trial, Talking Health, should determine whether health literacy or health numeracy mediates or moderates intervention changes in anthropometric/biological variables, physical activity behaviors, diet quality, and metabolic syndrome scores.

CHAPTER 3

Future Implications

Introduction

Low health literacy and low health numeracy are significant problems in the United States, affecting roughly 80 million people and 110 million people, respectively (*AHRQ, 2011; Huizinga et al., 2008*). Current research in this area focuses heavily on the role of health literacy and numeracy in all-cause mortality, perception of disease risk, health care costs, and access to care (*Berkman et al., 2004; Berkman et al., 2011; Reyna et al., 2009*); however, there is little to no research on the role of health literacy and numeracy and preventive behaviors, including diet and exercise, and preventive disease prevalence and control and research that has been done has yielded mixed results. There is a clear gap in the literature regarding cross-sectional relationships between health literacy and dietary intake or quality, physical activity, and body mass index, and a wider gap in the literature regarding health numeracy and these behaviors. Additionally, while certain subpopulations including those living in rural areas, have been shown to have increased rates of limited health literacy (*Zoellner et al., 2009; Zahnd et al., 2009*), there have been no known studies that focus on the aforementioned relationships.

This research aimed to determine the relationships between health literacy, health numeracy, demographic factors, anthropometric/biological variables (i.e., BMI, blood pressure, blood glucose, and blood lipids), physical activity behaviors, and diet quality, as well as determine whether health literacy and numeracy were predictive of metabolic syndrome, while controlling for demographic factors. While many demographic factors were related to health literacy a numeracy, analysis suggested that anthropometric/biological variables, physical activity behaviors, and diet quality did not differ by health literacy or numeracy level, with the exception of systolic blood pressure, diastolic blood pressure, and strength training activity. Additionally, health literacy and numeracy were not predictive of metabolic syndrome while

controlling for demographic factors. While few relationships were found, this research helps to fill an important gap in the literature regarding the prevalence of health literacy, health numeracy, health promoting activities, and chronic disease in rural southwest Virginia and reveals areas for future health literacy and numeracy research.

Future Implications

This research was part of a larger six-month, two-arm, matched-contact randomized controlled trial. Eligible participants are randomized to a behavioral intervention aiming to decrease sugar-sweetened beverage (SSB) intake (SipSmartER) or increase physical activity (Move More) through three small group classes, a teach back call, and 11 automated phone calls. The parent trial targets eight counties in rural southwest Virginia, of which seven are reported in this research. One of the first directions that could be taken is to include the final county in statistical analysis to determine whether any other trends in the relationships between health literacy, health numeracy, anthropometric/biological variables, physical activity behaviors, and diet quality emerge. Additionally, in the parent trial, 6-month follow-up and 18-month (12 months post-intervention) follow-up data was collected in addition to the baseline data reported in this research. With this data, future research should examine whether the intervention leads to changes in health literacy and/or health numeracy, which in turn leads to changes in anthropometric/biological variables, physical activity behaviors, diet quality, or metabolic syndrome scores. Also, researchers should examine whether health literacy and/or numeracy moderates intervention changes in these variables.

Beyond these directions, there are several other areas that could be explored. Currently, it is unclear why systolic blood pressure, diastolic blood pressure, and strength training activities were higher among those with low health literacy and numeracy compared to those with high health literacy and numeracy. Differences may be related to occupation or stress, but further research could more thoroughly explore these relationships. Similarly, future research could

further explore the relationships between health literacy, health numeracy, physical activity, and diet quality. One area to investigate is the built and food environments of these communities in southwest Virginia. Examining community resources and determining residents' access to these resources would not be a small undertaking, but doing so would help identify key factors that may influence diet quality and physical activity behaviors, such as access to healthy food options, access to physical activity outlets, and potential barriers to health promoting behaviors.

Finally, while it is necessary to explore the role of health literacy and numeracy in preventive health behaviors and the prevalence of chronic disease in rural populations, this population is a relatively narrow segment of the United States. Future research should also aim to examine the relationships between health literacy, health numeracy, anthropometric/biological variables, physical activity behaviors, and diet quality in a nationally representative sample in order to fully understand the extent to these relationships, or whether these relationships exist among the broader population.

Health literacy and numeracy have been shown to be necessary for a myriad of preventive health skills and chronic disease management including tracking daily calories and physical activity, reading and interpreting food labels, and diabetes self-management (*Huizinga et al., 2008; Rothman et al., 2006; Cavanaugh et al., 2008*). By exploring the role that health literacy and numeracy play in preventive health behaviors and chronic disease prevalence, and whether health literacy and numeracy mediate and/or moderate behavioral intervention effects, researchers can help to inform practice for registered dietitians and other health practitioners. A better understanding of these relationships can lead to targeted interventions and treatment options for low-health literate patients, which has the potential to lead to better health outcomes (*Taggart et al., 2012*).

Conclusion

Health literacy and numeracy research has grown significantly within the past decade; however, there are still gaps in the literature concerning the relationships between health literacy, health numeracy, and preventive health behaviors including diet and physical activity (*Berkman et al., 2004; Berkman et al., 2011; Reyna et al., 2009*). While this research found few cross-sectional relationships between these variables, it helped to fill this gap in the literature by exploring these relationships among residents of rural southwest Virginia. The current research also helped to illuminate several other areas for future research including examining if health literacy and health numeracy mediate or moderate intervention changes in anthropometric/biological variables, physical activity behaviors, diet quality, or metabolic syndrome scores as a part of the larger Talking Health trial; further exploring the role of unmeasured variables such as occupation, stress, or the built environment on these relationships; and, examining the relationships between health literacy, health numeracy, anthropometric/biological variables, physical activity behaviors, and diet quality in a nationally representative sample. Future health literacy and numeracy research will help to inform registered dietitians and other health practitioners on the role that health literacy and numeracy play in preventive health behaviors and chronic disease and ultimately help to improve health outcomes in the United States.

Table 1. Demographic Characteristics of Participants at Baseline (n = 264)

	n (%)	Mean \pm SD
Average Age (years)	--	41.1 \pm 13.5
Gender	--	--
Male	48 (18.2)	--
Female	216 (81.8)	--
Race	--	--
Caucasian	243 (92.0)	--
Other	21 (8.0)	--
Education	--	--
>High School	26 (9.6)	--
High School	55 (20.8)	--
Some College	98 (37.1)	--
College Graduate & Beyond	85 (32.2)	--
Income	--	--
<\$15,000	111 (42.0)	--
\$15 – 29,999	76 (28.8)	--
\$30 – 54,999	45 (17.0)	--
\geq \$55,000	32 (12.1)	--
NVS	--	3.96 \pm 1.96
Low	38 (14.4)	--
Moderate	51 (19.3)	--
High	175 (66.3)	--
REALM	--	61.49 \pm 9.49
< 9 th Grade	52 (19.7)	--
\geq 9 th Grade	212 (80.3)	--
SNS	--	4.18 \pm 1.32
Low	119 (45.4)	--
High	143 (54.6)	--
Average BMI (kg/m²)	--	33.2 \pm 9.2
Underweight (< 18.5)	5 (1.9)	--
Normal (18.5 – 24.9)	51 (19.3)	--
Overweight (25.0 – 29.9)	57 (21.6)	--
Obese (\geq 30.0)	151 (57.2)	--
Proportion Meeting MetS Criteria ^a	151 (57.2)	--
Average Systolic Blood Pressure (mmHg)	--	121.7 \pm 16.0
Proportion Meeting MetS Criteria ^a	73 (27.9)	--
Average Diastolic Blood Pressure (mmHg)	--	79.7 \pm 11.2
Proportion Meeting MetS Criteria ^a	78 (29.8)	--
Average Blood Glucose (mg/dL)	--	79.5 \pm 24.1
Proportion Meeting MetS Criteria ^a	15 (5.7)	--
Average Triglycerides (mg/dL)	--	128.6 \pm 77.4
Proportion Meeting MetS Criteria ^a	74 (28.2)	--
Average HDL Cholesterol (mg/dL)	--	46.3 \pm 14.6
Proportion Meeting MetS Criteria ^a	160 (61.1)	--
MetS^a	--	1.9 \pm 1.2
Yes	76 (71.0)	--
No	186 (29.0)	--

^a MetS criteria includes 3 of the following: BMI \geq 30 kg/m², blood pressure \geq 135 mmHg and/or 85 mmHg, FPG \geq 100 mg/dL, TG \geq 150 mg/dL, HDL \leq 40 mg/dL (men) or \leq 50 mg/dL (women).

Table 2. Correlations between Health Literacy and Numeracy Measures (n = 264)

	NVS Total	NVS Reading	NVS Math	REALM	SNS
NVS Total^a	---				
NVS Reading^b	.754**	---			
NVS Math^c	.925**	.456**	---		
REALM^d	.472**	.329**	.452**	---	
SNS^e	.283**	.016	.384**	.189**	---

** Correlation is significant at the 0.01 level (2-tailed).

^aNVS: Newest Vital Sign, Scale of 0-6, (0-1 = High Likelihood of Limited Health Literacy, 2-3 = Possibility of Limited Health Literacy, 4-6 = Adequate Health Literacy)

^bNVS Reading: Questions 5&6 on NVS, Score of either 0 or 2 (# answered correctly)

^cNVS Math: Questions 1-4 on NVS, Score of 0-4 (# answered correctly)

^dREALM: Rapid Estimate of Adult Literacy in Medicine, Scale of 0-66 (0-18 = 3rd Grade Reading Level and Below, 19-44 = 4th Grade to 6th Grade, 45-60 = 7th Grade to 8th Grade, 61-66 = High School)

^eSNS: Subjective Numeracy Scale, Scale of 0-6 (0 = Preference for Words, 6 = Preference for Numbers)

Table 3. Differences in Health Literacy and Numeracy Status by Demographic Characteristics

Demographic Characteristics	n (%)	NVS		REALM		SNS ^a	
		Mean (SD)	Sig	Mean (SD)	Sig	Mean (SD)	Sig
Age(years)							
18 – 30	69 (26.1)	4.01 (1.97)	F = 2.36 p = .05	62.01 (7.80)	F = 1.08 p = .37	4.13 (1.29)	F = 1.46 p = .21
31 – 40	59 (22.3)	4.58 (1.68)*		62.59 (9.33)		4.07 (1.27)	
41 – 50	62 (23.5)	3.79 (1.80)		62.09 (8.77)		4.02 (1.41)	
51 – 60	56 (21.2)	3.57 (2.14)*		59.37 (11.86)		4.31 (1.25)	
≥61	18 (6.8)	3.55 (2.45)		60.33 (9.94)		4.79 (1.35)	
Gender							
Male	48 (18.2)	3.54 (2.31)	F = 2.70 p = .102	59.64 (13.77)	F = 2.22 p = .14	4.77 (1.30)	F = 12.40 p = .001
Female	216 (81.8)	4.05 (1.87)		61.89 (8.23)		4.04 (1.29)	
Race							
Caucasian	243 (92.0)	4.04 (1.93)	F = 4.49 p = .03	61.82 (8.79)	F = 3.74 p = .05	4.14 (1.33)	F = 1.80 p = .18
Other	21 (8.0)	3.09 (2.23)		57.67 (15.23)		4.55 (1.05)	
Education							
<High School	26 (9.8)	2.00 (1.77) [#]	F = 20.97 p < .001	51.31 (14.12) ^{&#}	F = 21.06 p < .001	3.09 (1.18) [#]	F = 11.01 p < .001
High School	55 (20.8)	3.07 (1.98) ^{\$}		57.82 (14.91) ^{&\$}		3.84 (1.04) ^{\$}	
Some College	98 (37.1)	4.49 (1.75) ^{##}		63.89 (2.76) ^{##}		4.29 (1.36) [#]	
College	85 (32.2)	4.53 (1.67) ^{##}		64.21 (3.96) ^{##}		4.59 (1.27) ^{##}	
Graduate & Beyond							
Annual Income							
<\$15,000	111 (42.0)	3.13 (2.05) [^]	F = 13.88 p < .001	58.53 (13.04) ^{**}	F = 6.80 p < .001	3.66 (1.19) ^{##}	F = 14.45 p < .001
\$15 – 29,999	76 (28.8)	4.54 (1.63) [^]		63.10 (5.89) ^{**}		4.32 (1.35) ^{##\$\$}	
\$30 – 54,999	45 (17.0)	4.29 (1.74) [^]		63.93 (2.82) ^{**}		4.52 (1.21) ^{##}	
≥\$55,000	32 (12.1)	5.00 (1.61) [^]		64.47 (3.18) ^{**}		5.14 (1.05) ^{##\$\$}	
Overall	264	3.96 (1.96)				61.49 (9.49)	

^aDue to missing data, N = 262

*Post hoc Tukey test indicates significant differences between groups: 31-40 years vs.51-60 years (p = .05).

#Post hoc Tukey test indicates significant differences between groups: <HS vs. Some college (p < .001); <HS vs College graduate & beyond (p < .001).

\$Post hoc Tukey test indicates significant differences between groups: HS vs. Some college (p < .001); HS vs. College graduate & beyond (p < .001).

&Post hoc Tukey test indicates significant differences between groups: <HS vs. HS (p = .01).

^Post hoc Tukey test indicates significant differences between groups: <\$15,000 vs. \$15-29,999 (p = .003); <\$15,000 vs. \$30-54,999 (p < .001); <\$15,000 vs. >\$55,000 (p < .001).

**Post hoc Tukey test indicates significant differences between groups: <\$15,000 vs. \$15-29,999 (p = .005); <\$15,000 vs. \$30-54,999 (p = .006); <\$15,000 vs. >\$55,000 (p = .008).

##Post hoc Tukey test indicates significant differences between groups: <\$15,000 vs. \$15-29,999 (p = .002); <\$15,000 vs. \$30-54,999 (p = .001); <\$15,000 vs. >\$55,000 (p < .001).

\$\$Post hoc Tukey test indicates significant differences between groups: \$15 – 29,999 vs. >\$55,000 (p = .009).

Table 4. BMI, Blood Pressure, and Fasting Plasma Glucose

	n (%)	Body Mass Index (kg/m ²)		Systolic Blood Pressure (mmHg)		Diastolic Blood Pressure (mmHg)		Glucose (mg/dL)	
		Mean (SD)	Sig	Mean (SD)	Sig	Mean (SD)	Sig	Mean (SD)	Sig
NVS Low Medium High	38 (14.4) 51 (19.3) 175 (66.3)	32.9 (8.7) 33.1 (10.9) 33.3 (8.8)	F = 0.03 p = .97	127.9 (17.8)* 120.2 (13.5) 120.8 (16.1)*	F = 3.39 p = .04	81.6 (11.2) 76.9 (10.5) 80.1 (11.3)	F = 2.22 p = .11	86.0 (33.5) 79.6 (24.7) 77.9 (21.3)	F = 1.74 p = .18
REALM < 9 th Grade ≥ 9 th Grade	52 (19.7) 212 (80.3)	32.9 (9.7) 33.2 (9.1)	F = 0.03 p = .86	120.1 (15.3) 122.1 (16.2)	F = 0.69 p = .41	76.4 (10.5) 80.5 (11.2)	F = 5.79 p = .02	79.1 (15.0) 79.5 (25.9)	F = 0.01 p = .91
SNS^a Low High	119 (45.4) 143 (54.6)	33.3 (8.4) 33.1 (9.2)	F = 0.02 p = .88	119.3 (15.7) 123.5 (16.1)	F = 4.55 p = .03	78.4 (10.1) 80.6 (11.9)	F = 2.66 p = .10	81.9 (28.5) 77.3 (19.9)	F = 2.27 p = .13
Overall	264	33.2 (9.2)		121.7 (16.0)		79.7 (11.2)		79.5 (24.1)	

^aDue to missing data, N = 262

*Post hoc Tukey test indicates significant differences between groups: LHL 127.9 (SD = 17.8); HHL 120.8 (SD = 16.1) (p = .04).

Table 5. Fasting Blood Lipids

	n (%)	Total Cholesterol (mg/dL)		LDL Cholesterol (mg/dL)		HDL Cholesterol (mg/dL)		Triglycerides (mg/dL)	
		Mean (SD)	Sig	Mean (SD)	Sig	Mean (SD)	Sig	Mean (SD)	Sig
NVS									
Low	38 (14.4)	170.1 (40.3)	F = 1.23	98.2 (32.0)	F = 0.55	45.8 (18.8)	F = 0.45	147.5 (82.6)	F = 1.33
Medium	51 (19.3)	158.3 (40.1)	p = .29	92.4 (33.1)	p = .58	44.5 (15.0)	p = .64	124.3 (69.5)	p = .27
High	175 (66.3)	165.8 (35.4)		97.5 (30.1)		46.8 (15.0)		125.8 (78.2)	
REALM									
< 9 th Grade	52 (19.7)	158.8 (38.5)	F = 1.81	91.9 (31.0)	F = 1.35	46.3 (16.3)	F = 0.00	130.7 (75.6)	F = 0.05
≥ 9 th Grade	212 (80.3)	166.5 (36.7)	p = .18	97.8 (30.8)	p = .25	46.2 (15.4)	p = .96	128.1 (77.9)	p = .83
SNS^a									
Low	119 (45.4)	160.6 (36.7)	F = 3.32	94.7 (29.1)	F = 0.81	45.2 (16.2)	F = 0.89	134.9 (84.6)	F = 1.59
High	143 (54.6)	168.7 (37.4)	p = .08	98.4 (32.3)	p = .37	47.0 (14.9)	p = .35	122.8 (70.1)	p = .21
Overall	264	165.0 (37.2)		96.8 (30.9)		46.2 (15.6)		128.3 (77.1)	

^aDue to missing data, N = 262

Table 6. Physical Activity Behaviors

	n (%)	Godin Vigorous/Strenuous Total Activity (min/wk)		Godin Vigorous/Strenuous + Moderate Total Activity (min/wk)		Godin Moderate Total Activity (min/wk)		Godin Strength Total Activity (min/wk)	
		Mean (SD)	Sig	Mean (SD)	Sig	Mean (SD)	Sig	Mean (SD)	Sig
NVS Low Medium High	38 (14.4) 51 (19.3) 175 (66.3)	16.3 (69.6) 25.9 (80.7) 24.8 (72.8)	F = 0.23 p = .79	72.1 (134.9) 81.6 (154.5) 71.2 (127.0)	F = 0.12 p = .89	55.8 (117.3) 55.7 (120.9) 46.4 (99.3)	F = 0.23 p = .80	33.8 (106.2)* 12.3 (37.7) 5.3 (26.6)*	F = 5.46 p = .01
REALM < 9 th Grade ≥ 9 th Grade	52 (19.7) 212 (80.3)	22.9 (77.8) 24.0 (72.9)	F = 0.01 p = .92	82.5 (174.6) 71.1 (121.6)	F = 0.03 p = .58	59.6 (155.8) 47.1 (90.1)	F = 0.58 p = .45	13.5 (76.4) 10.0 (40.1)	F = 0.21 p = .64
SNS^a Low High	119 (45.4) 143 (54.6)	19.9 (78.4) 26.9 (70.2)	F = 0.59 p = .44	67.2 (135.2) 78.9 (132.9)	F = 0.50 p = .48	47.3 (108.0) 51.9 (105.4)	F = 0.12 p = .72	4.8 (23.5) 15.8 (63.0)	F = 3.25 p = .07
Overall	264	23.7 (73.9)		73.6 (133.8)		49.8 (106.4)		10.8 (49.4)	

^aDue to missing data, N = 262

*Post hoc Tukey test indicates significant differences between groups: LHL 33.8 (SD = 106.2) minutes per week; HHL 5.3 (SD = 26.6) minutes per week (p = .003).

Table 7. Average Daily SSB Intake and Healthy Eating Index Score

	n (%)	Average Daily SSB Intake (kcal)		Healthy Eating Index Score	
		Mean (SD)	Sig	Mean (SD)	Sig
NVS					
Low	32 (14.3)	254.3 (225.4)	F = 1.57 p = .21	41.0 (11.5)	F = 0.65 p = .52
Medium	41 (18.3)	301.5 (287.6)		43.7 (10.7)	
High	151 (67.4)	364.7 (385.9)		43.6 (12.6)	
REALM					
< 9 th Grade	52 (19.7)	307.1 (265.9)	F = 0.38 p = .54	42.1 (11.2)	F = 0.51 p = .47
≥ 9 th Grade	182 (81.2)	344.3 (369.1)		43.6 (12.4)	
SNS^a					
Low	103 (46.3)	352.6 (328.5)	F = 0.25 p = .61	42.4 (13.1)	F = 0.82 p = .37
High	119 (53.6)	328.6 (372.9)		43.9 (11.3)	
Overall	224^b	337.3 (351.8)		43.3 (12.1)	

^aDue to missing data, N = 222

^b Average daily SSB intake and HEI scores for Wythe County are currently being entered into the database and are not included in this analysis. This table represents data from Lee County through Wise County.

Table 8. Using Health Literacy and Demographic Variables to Predict Metabolic Syndrome (n = 264)

		Metabolic Syndrome	
Variables	Units	b	p-value
NVS	Scores	-0.32	.75
<i>Age</i>	Years	0.09	.16
<i>Male</i>	Dummy	-0.03	.61
<i>White</i>	Dummy	0.00	.99
<i>Education level</i>	Categories	0.06	.39
<i>Income</i>	Categories	-0.17	.02
R-squared			0.03
REALM	Scores	0.02	.76
<i>Age</i>	Years	1.54	.13
<i>Male</i>	Dummy	-0.04	.57
<i>White</i>	Dummy	0.01	.99
<i>Education level</i>	Categories	0.05	.52
<i>Income</i>	Categories	-0.18	.01
R-squared			0.03
SNS^a	Scores	0.00	.99
<i>Age</i>	Years	0.09	.15
<i>Male</i>	Dummy	-0.04	.56
<i>White</i>	Dummy	0.00	.95
<i>Education level</i>	Categories	0.06	.38
<i>Income</i>	Categories	-0.18	.01
R-squared			0.03

^aDue to missing data, N = 262

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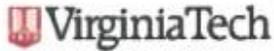
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Appendices

Appendix A: IRB Approval



Office of Research Compliance
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24060
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website <http://www.irb.vt.edu>

MEMORANDUM

DATE: January 10, 2013
TO: Jamie M Zoelner Dr, Paul Andrew Estabrooks, Yvonne Chen, Brenda Davy, Wen You
FROM: Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)
PROTOCOL TITLE: Talking Health- Main Trial
IRB NUMBER: 12-090

Effective January 9, 2013, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

<http://www.irb.vt.edu/pages/responsibilities.htm>

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As: Expedited, under 45 CFR 46.110 category(ies) 7
Protocol Approval Date: February 1, 2013
Protocol Expiration Date: January 31, 2014
Continuing Review Due Date*: January 17, 2014

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution.

Date*	OSP Number	Sponsor	Grant Comparison Conducted?
07/11/2012	10157901	National Institutes of Health	Compared on 01/27/2012

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

Appendix B: Informed Consent

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY Informed Consent for Participants In Research Projects Involving Human Subjects

Project Title: Talking Health Project

Principle Investigator: Jamie Zoellner, PhD, RD, Department of Human Nutrition, Foods and Exercise

Co Investigators:

Paul Estabrooks, PhD, Department of Human Nutrition, Foods and Exercise

Brenda Davy, PhD, RD, Department of Human Nutrition, Foods and Exercise

Wen You, PhD, Department of Agricultural and Applied Economics

Yvonne Chen, PhD, Department of Communication

I. Purpose of this Research:

Virginia Tech's Human Nutrition, Foods and Exercise Department is offering a free 6-month health program with follow-up health screenings for one year. The goal of this program is to improve your health behaviors, such as sugar intake or physical activity behaviors.

II. Procedures

This study will include health screenings and an education program. In this study, you will be randomized- like a flip of a coin- into one of two groups, either the sugar intake group or the physical activity group. Randomization means you will not have a choice which group you belong to. You must agree to be randomized to be involved in this study.

Health Screenings

As a part of the program, you will need to attend 3 health screenings. The first one will be at the beginning of the program; the second one will be at the end of the program (6 months), and the third one will be a follow-up at 18-months. The health screening data will be collected in-person and includes:

- Surveys about your food and drink behaviors, physical activity behaviors, health status, and quality of life
- Height and weight
- Blood pressure
- Finger-stick blood sample to measure blood sugar and cholesterol levels

You will be asked to complete the screening on two different days, and each day will take about 45-60 minutes.

After each of the 3 health screening, you will receive two more telephone calls where you will be asked to report your food, drink, and physical activity for the previous day. Each of these phone calls will last about 20 minutes.

The total time for the health screenings is about 7-8 hours over the course of the 18-month program.

Education Program

The education program will last for 6 months. During this time you will be asked to:

- attend 3 small group sessions, each lasting about 2 hours
- complete 11 Interactive Voice Response telephone calls to help you track your behaviors and reach your goals, each lasting about 10-15 minutes.

The total time for the education program is about 7-8 hours.

III. Compensation

Virginia Tech Institutional Review Board Project No. 12-090
Approved January 6, 2014 to January 31, 2015

You will get a gift card for your time involved in completing each of the health screenings, including:

- beginning of the program: \$25 gift card
- end of the program (at 6-months): \$50 gift card
- follow-up (at 18-months): \$75 gift card

You will also get small non-monetary prizes at the group sessions to help you reach your goals.

IV. Risks

There are minimal risks for being involved in this study. It is possible that the health screening could cause stress or anxiety for you. You will always have the right to refuse to participate or to answer any questions in the health screening. If you become too tired during the health screening, you can take a break or finish on another day.

Possible risks related to the finger stick include a small amount of bleeding, temporary discomfort, and soreness.

The main risk of taking part in the physical activity program is a small risk associated with starting a physical activity program, if you have not been physically active. To lower this risk, you will always participate in the physical activity sessions at your own pace. Inappropriate levels of physical activity could lead to muscle and bone injuries during or following physical activity. Further, it is possible that cardiovascular and respiratory related adverse events could occur. In order to protect against these risks, the study will guide participants in selecting appropriate levels and intensity of physical activity.

Although not expected, if you must seek medical or counseling services as a direct result of your participation in this study, neither the investigator nor the University has funds to pay for such services. The costs of any such services must be paid by you.

This study may include risks that are unknown at this time. You will be informed of significant new findings that develop during the course of this study that may affect your willingness to continue to participate in this study.

V. Benefits

If you decide to take part in this study, there is no guarantee that you will experience any changes in your health, regardless of which group you are randomized to. However, participants may receive the following benefits: learning appropriate behavioral change strategies to improve their sugar intake or physical activity behaviors, modest weight loss, and/or improvement in health conditions.

At each of the health screenings you will receive a handout that explains the results of your lab values.

Furthermore, to cover your time spent completing the health screenings; you will receive a gift card incentive.

VI. Confidentiality

Several steps will be taken to ensure confidentiality, including but not limited to adequate training of personnel. Only certified and trained study personnel will have access to information about you obtained for this study. This information will be kept confidential and will not be released without your written permission unless compelled by law. We will use study ID numbers in order to enhance the confidentiality of your information. At the start of the study you will be assigned a study ID number, so that you will only be identified by that number for study purposes. It is possible that the Institutional Review Board (IRB) may view this study's data for auditing purposes. The IRB is responsible for oversight of the protection of human subjects involved in research. All identifiable information about you will be destroyed at the earliest opportunity following the completion of the study.

VII. Freedom to Withdraw

Participation in this study is completely voluntary. You are free to stop participating in the study at any time without penalty. If you choose to withdraw, please contact the project director to let them know of your decision. You are also free not to answer any questions or to complete any portions of the study that you choose not to without penalty. It is also possible that the study sponsor or other regulatory agencies or boards may terminate the study at any time.

VIII. Participant's Responsibilities

I voluntarily agree to participate in this study. I agree to:

1. Complete 3 health screenings which includes surveys, height, weight, blood pressure, and a finger-stick blood sample, each lasting 45-60 minutes for 2 days
2. Complete 6 telephone recalls, each lasting about 20 minutes
3. Attend 3 small group educational sessions, each lasting about 2 hours
4. Complete 11 Interactive Voice Response telephone calls, each lasting 10-15 minutes

IX. Participant's Permission

I have read the consent form and conditions of this project. I have had all of my questions answered. I hereby acknowledge the above and give my voluntary consent:

_____ Date: _____
Participant signature

Participant Name (Please Print)

Should I have any pertinent questions about this research or its conduct, research participants' rights, and whom to contact in the event of a research related injury to the subject, I may contact:

Terri Corsi, Project Director
Department of Nutrition, Foods and Exercise
Integrated Life Sciences Building 23, Room 1032
1981 Kraft Drive (0913), Blacksburg, VA 24061
540-231-4325
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David M. Moore, Chair of Virginia Tech Institutional Review Board
For the Protection of Human Subjects
Office of Research Compliance
540-231-4991
moored@vt.edu

Appendix C: Newest Vital Sign (NVS)

Nutrition Facts			
Serving Size		½ cup	
Servings per container		4	
Amount per serving			
Calories	250	Fat Cal	120
			%DV
Total Fat	13g		20%
Sat Fat	9g		40%
Cholesterol	28mg		12%
Sodium	55mg		2%
Total Carbohydrate	30g		12%
Dietary Fiber	2g		
Sugars	23g		
Protein	4g		8%

*Percentage Daily Values (DV) are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

Ingredients: Cream, Skim Milk, Liquid Sugar, Water, Egg Yolks, Brown Sugar, Milkfat, Peanut Oil, Sugar, Butter, Salt, Carrageenan, Vanilla Extract.

[PARTICIPANT ID Number]:

[DATA COLLECTOR Initials]:

Newest Vital Sign (NVS)

[SHOW NUTRITION LABEL HANDCARD]

[READ TO RESPONDENT]: "This next section only takes a few minutes because there are only 5-6 questions. Please use the nutrition label provided to answer the following questions. This information is on the back of a container of one pint of ice cream."

[NOTE: Provide respondent with scratch paper if necessary.]

NVS1. If you eat the entire container, how many calories will you eat?

[RECORD ANSWER or check below]

[98] I don't know/Refused to answer

NVS2. If you are allowed to eat 60 grams of carbohydrate as a snack, how much ice cream could you have?

[RECORD ANSWER or check below]

[NOTE: IF PARTICIPANT ANSWERS 'Two servings' ASK "How much ice cream would that be if you were to measure it into a bowl?]

[98] I don't know/Refused to answer

NVS3. Your doctor advises you to reduce the amount of saturated fat in your diet. You usually have a total of 42 grams of saturated fat each day, which includes one serving of ice cream. If you stop eating the one serving of ice cream, how many grams of saturated fat would you be eating each day?

[RECORD ANSWER or check below]

[98] I don't know/Refused to answer

[PARTICIPANT ID Number]: |__||__||__||__||__||

NVS4. If you usually eat 2500 calories in a day, what percentage of your daily value of calories will you be eating if you eat one serving?

|_____|
[RECORD ANSWER or check below]

[98] I don't know/Refused to answer

NVS5. Pretend that you are allergic to the following substances: Penicillin, peanuts, latex gloves, and bee stings. Is it safe for you to eat this ice cream?

|_____|
[RECORD ANSWER or check below]

[98] I don't know/Refused to answer

NVS6. [ASK ONLY IF THE PATIENT RESPONDS "NO" TO QUESTION 5].
Why not?

|_____|
[RECORD ANSWER or check below]

[98] I don't know/Refused to answer

Appendix D: Rapid Estimate of Adult Literacy in Medicine (REALM)

RAPID ESTIMATE OF ADULT LITERACY IN MEDICINE
(REALM) Examiner's Instruction Sheet

Terry Davis, PhD, Michael Crouch, MN, Sandy Long, PhD

The Rapid Estimate of Adult Literacy in Medicine (REALM) is a screening instrument to assess an adult patient's ability to read common medical words and lay terms for body parts and illnesses. It is designed to assess medical professionals in estimating a patient's literacy level so that the appropriate level of patient education materials or oral instructions may be used. The test takes two to three minutes to administer and score. The REALM has been correlated with other standardized tests (Family Medicine, 1993; 25:391-5).

Directions to the Examiner:

1. **Examiner should say to the patient:**
"This survey is to help us figure out the best type of patient education materials to give you. The survey only takes 2 to 3 minutes to do"
2. Give the patient a laminated copy of the "REALM" Patient Word List.
3. Examiner should hold an unlaminated "REALM" Score Sheet on a clipboard at an angle so that the patient is not distracted by your scoring procedure.
4. Examiner should say:
"I want to hear you read as many words as you can from this list. Begin with the first word on List 1 and read aloud. When you come to a word you cannot read, do the best you can or say "blank" and go on to the next word."
5. If the patient takes more than five seconds on a word say "blank" and point to the next word, if necessary, to move the patient along. If the patient begins to miss every word; have him/her pronounce only known words.
6. Count as an error any word not attempted or mispronounced. Score by:
 - ◆ (/) after each mispronounced word.
 - ◆ (-) after each word not attempted.
 - ◆ (+) after each word pronounced correctly.
7. Count the number of correct words for each list and record the numbers in the "SCORE box. Total the numbers and match the total score with its grade equivalent in the table below.
8. Record the "RealM" generated reading level on the Examiner's Score Sheet and in the Education/Learning History section of the Social and Patient Education History assessment form in the Medical Record.

GRADE EQUIVALENT

Raw Score	Grade Range	
0-18	3 rd Grade and Below	Will not be able to read most low literacy materials; will need repeated oral instructions, materials composed primarily of illustrations, or audio or video tapes.
19-44	4 th to 6 th Grade	Will need low literacy materials; may not be able to read prescription labels.
45-60	7 th to 8 th Grade	Will struggle with most patient education materials.
61-66	High School	Will be able to read most patient education materials.

Red Lake Hospital
 Red Lake, MN 56671
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RAPID ESTIMATE OF ADULT LITERACY IN MEDICINE (REALM)

Terry Davis, PhD, Michael Crouch, MD, Sandy Long, PhD

Chart # _____

Examine date: _____

Name: _____

Birth date: _____

REALM generated reading level: _____

Grade completed: _____

List 1	List 2	List 3
Fat _____	Fatigue _____	Allergic _____
Flu _____	Pelvic _____	Menstrual _____
Pill _____	Jaundice _____	Testicle _____
Dose _____	Infection _____	Colitis _____
Eye _____	Exercise _____	Emergency _____
Stress _____	Behavior _____	Medication _____
Smear _____	Prescription _____	Occupation _____
Nerves _____	Notify _____	Sexually _____
Germs _____	Gallbladder _____	Alcoholism _____
Meals _____	Calories _____	Irritation _____
Disease _____	Depression _____	Constipation _____
Cancer _____	Miscarriage _____	Gonorrhea _____
Caffeine _____	Pregnancy _____	Inflammatory _____
Attack _____	Arthritis _____	Diabetes _____
Kidney _____	Nutrition _____	Hepatitis _____
Hormones _____	Menopause _____	Antibiotics _____
Herpes _____	Appendix _____	Diagnosis _____
Seizure _____	Abnormal _____	Potassium _____
Bowel _____	Syphilis _____	Anemia _____
Asthma _____	Hemorrhoids _____	Obesity _____
Rectal _____	Nausea _____	Osteoporosis _____
Incest _____	Directed _____	Impetigo _____
# of (+) Responses in List 1: _____	# of (+) Responses in List 2: _____	# of (+) Responses in List 3: _____

LEGEND: (+)=Correct (-)=Word not attempted (/)=Mispronounced word

Raw Score: _____

Red Lake Hospital, Red Lake MN 56671
4/98/JMcD

Appendix E: Subjective Numeracy Scale (SNS)

Subjective Numeracy Scale (SNS)

The Subjective Numeracy Scale (SNS) is a self-report measure of perceived ability to perform various mathematical tasks and preference for the use of numerical versus prose information. The 8-item scale contains no mathematics questions and has no correct or incorrect answers. Instead, it consists of 4 questions asking respondents to assess their numerical ability in different contexts and 4 questions asking them to state their preferences for the presentation of numerical and probabilistic information. The SNS is both reliable and highly correlated with the Lipkus, Samsa & Rimer (2001) numeracy measure, and it has been validated in both risk communication and utility elicitation domains.

Scoring Instructions:

All questions scored as marked (1-6) except Question 7 which is reverse coded (6-1).

SNS: Average rating across all 8 questions (w/ Q7 reverse coded)

SNS ability subscale: Average rating on Questions 1-4

SNS preference subscale: Average rating on Questions 5-8 (w/ Q7 reverse coded)

To cite the scale, please use the following reference:

Fagerlin, A., Zikmund-Fisher, B.J., Ubel, P.A., Jankovic, A., Derry, H.A., & Smith, D.M. Measuring numeracy without a math test: Development of the Subjective Numeracy Scale (SNS). *Medical Decision Making*, 2007: 27: 672-680.

In any discussions about the validation of the scale, please use the following reference:

Zikmund-Fisher, B.J., Smith, D.M., Ubel, P.A., Fagerlin, A. Validation of the subjective numeracy scale (SNS): Effects of low numeracy on comprehension of risk communications and utility elicitation. *Medical Decision Making*, 2007: 27: 663-671.

For each of the following questions, please check the box that best reflects **how good you are at doing the following things**:

1. How good are you at working with fractions?

₁ ₂ ₃ ₄ ₅ ₆

**Not at all
good**

**Extremely
good**

2. How good are you at working with percentages?

₁ ₂ ₃ ₄ ₅ ₆

**Not at all
good**

**Extremely
good**

3. How good are you at calculating a 15% tip?

₁ ₂ ₃ ₄ ₅ ₆

**Not at all
good**

**Extremely
good**

4. How good are you at figuring out how much a shirt will cost if it is 25% off?

₁ ₂ ₃ ₄ ₅ ₆

**Not at all
good**

**Extremely
good**

For each of the following questions, please check the box that **best reflects your answer**:

5. When reading the newspaper, how **helpful** do you find tables and graphs that are parts of a story?

₁ ₂ ₃ ₄ ₅ ₆

**Not at all
helpful**

**Extremely
helpful**

6. When people tell you the chance of something happening, do you prefer that they use **words** ("it rarely happens") or **numbers** ("there's a 1% chance")?

₁ ₂ ₃ ₄ ₅ ₆

**Always Prefer
Words**

**Always Prefer
Numbers**

7. When you hear a weather forecast, do you prefer predictions using **percentages** (e.g., "there will be a 20% chance of rain today") or predictions using only **words** (e.g., "there is a small chance of rain today")?

₁ ₂ ₃ ₄ ₅ ₆

**Always Prefer
Percentages**

**Always Prefer
Words**

8. How **often** do you find numerical information to be useful?

₁ ₂ ₃ ₄ ₅ ₆

Never

Very Often

Appendix F: Godin Leisure Time Physical Activity Questionnaire

Godin Assessment

[DATA COLLECTOR Initials]: |_|_|_|_|

[PARTICIPANT ID]: |_|_|_|_|_|_|_|_|_|_|

Physical Activity (PA)

[SHOW PHYSICAL ACTIVITY HANDCARD 1]

[READ TO RESPONDENT]:

“The next set of questions will ask you about the time you spent being physically active in the last 7 days. I will ask you about strenuous, moderate, mild, and strength training exercises.

Note that the main difference between the three categories is the intensity of the exercise. Please designate a type of exercise as either strenuous or moderate and not both.”

Only count exercise that was done during your free time. Do not count exercise that is a part of your job or housework.”

PA01. Considering the past week (7 days), how many times on average do you do the following kinds of exercise for more than 15 minutes during your free time?

- a. Strenuous exercise (heart beats rapidly)
(i.e. running, jogging, hockey, football, soccer, squash, basketball, cross country, skiing, judo, roller skating, vigorous swimming, vigorous long-distance bicycling)

|_____| [RECORD times per week]

|_____| [RECORD minutes per time]

- b. Moderate exercise (not exhausting)
(i.e. fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, popular and folk dancing)

|_____| [RECORD times per week]

|_____| [RECORD minutes per time]

- c. Mild exercise (minimal effort) (i.e. yoga, archery, fishing from river bend, bowling, golf, easy walking)

_____ | [RECORD times per week]

_____ | [RECORD minutes per time]

- d. Strength Training Exercise (e.g., weight lifting)

_____ | [RECORD times per week]

_____ | [RECORD minutes per time]

[SHOW PHYSICAL ACTIVITY HANDCARD 2]

_____ | PA02. Considering the past week (7 days), during your leisure time, how often do you engage in any regular activity long enough to work up a sweat (heart beats rapidly)?

[1] Often

[2] Sometimes

[3] Rarely or Never