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Grip Strength, Multimorbidity, and Disability

Amy M. Yorke
Western Michigan University, amyorke@umflint.edu

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by

Amy M. Yorke

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Doctoral Committee:

Amy B. Curtis, Ph.D., Chair
Michael J. Shoemaker, Ph.D.
Eric Vangsnes, Ph.D.

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Amy M. Yorke, Ph.D.

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The presence of two or more chronic health conditions, also known as multimorbidity, is one of the most prevalent health disorders experienced by adults. Adults with multimorbidity and functional limitations represent clinical and financial challenges to the current health care system. The purpose of this three-paper dissertation is to examine the relationship between grip strength, multimorbidity, and the prediction of disability in adults. Data from the 2008 Health and Retirement Study (HRS), a nationally representative, longitudinal study completed on Americans age 50 years and over, are used for the dissertation.

The objective of the first paper is to investigate the relationship between grip strength (measured in kilograms, kg) and chronic disease status. The results of this study indicate that when controlling for age and gender, as the number of chronic diseases increased, grip strength decreases. The findings are statistically significant.

Grip strength normative values are computed for the second paper. Grip strength norms are stratified by gender (male, female), age (by decades), and chronic disease status (0, 1, 2, >3). The average grip strength for males ranges from 28.10 kg (80 years and older with three or more chronic diseases) to 46.81 kg (50–59 years with zero chronic diseases). Average right grip strength for females ranges from 16.76 kg

(80 years and older with two chronic diseases) to 27.48 kg (50–59 years with zero chronic diseases).

The third paper investigates a grip strength cutoff value that can be used to predict upper extremity (UE) or lower extremity (LE) disability in adults with and without multimorbidity. Receiver Operating Characteristic curves are calculated for sample, stratified by gender and chronic disease status. In summary, males without multimorbidity and a grip strength of<41kg and males with multimorbidity and a grip strength of <37 kg are anticipated to develop UE and LE disability. In females without multimorbidity and a grip strength of <25 kg and females with multimorbidity and a grip strength of <23 kg are anticipated to develop UE and LE disability

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CHAPTER 1

THE INVESTIGATION OF THE RELATIONSHIPS AMONG GRIP STRENGTH, MULTIMORBIDITY, AND DISABILITY

Introduction

According to the United States (U.S.) Census Bureau, there were 40.3 million adults aged 65 years and older in 2011, and by 2050 this population is expected to increase to 88.5 million or 20% of the U.S. population.[1,2] The most prevalent chronic condition experienced by aging adults is multimorbidity, defined as the presence of two or more chronic conditions.[3,4] Currently, one in four American adults younger than age 65 and almost three in four adults aged 65 years and older have multimorbidity.[3,4] Maintaining health and functional independence is a priority of aging adults.[5] The onset of disability with aging is commonly related to the presence of chronic diseases.[6] Twenty-five percent of adults with chronic diseases have one or more limitations in activities of daily living (ADLs).[4] Adults with chronic conditions and functional limitations spend three times the amount for health care as compared to those with only chronic conditions.[7] Muscle weakness is associated with aging and chronic diseases.[8] Muscle strength has been promoted as the single best measure of age-related muscle change and is associated with functional limitations.[9] Grip strength has been promoted as a surrogate measure of overall muscle strength and recommended as an assessment measure of an aging adult due to its predictive abilities and ease of use.[10] The overarching goal of this dissertation is to provide additional information on the relationship between

grip strength, multimorbidity, and disability in order to promote cost-effective, evidence-based care that focuses on maximizing function and preventing disability in aging Americans with multimorbidity.

Grip Strength, Multimorbidity, and Disability

Contraction of the intrinsic and extrinsic hand muscles causing flexion of the fingers is measured as grip strength.[11] Measuring grip strength with a hand-held dynamometer is simple, affordable, and reliable.[12] A person with impaired grip strength may have difficulty completing common ADLs that involve carrying, lifting, and manipulating objects.[13] Grip strength has been reported to be predictive of disability and mortality.[12] Decreased grip strength is often associated with the presence of a single chronic disease, such as arthritis, cancer, heart disease, lung disease, or diabetes.[14-19] In addition, in a recent study (2012) completed in China, decreased grip strength was found to be associated with increased odds of having multiple chronic diseases.[20]

Multimorbidity is a growing public health concern.[3,4] The prevalence of multimorbidity increases with age and it is anticipated to impact 171 million Americans by 2030.[4] Multiple chronic health conditions are associated with an increased risk of death, decreased quality of life, and disability.[7,21] Despite the high cost of multimorbidity and disability, the current U.S. health care system is designed around the management of a single disease with little to no consideration for multimorbidity or preventing disability.[3,4] Increasing costs and inadequate health care have pressed governmental and professional organizations to call for significant changes in the care of adults with multimorbidity from the current single disease orientation to one focused on the

patient.[22,23] Traditionally in the medical model, primary prevention of a disease was the method of averting disability; however, the International Classification of Functioning (ICF) model proposed by the World Health Organization in 2001 represents the complexity of disability as an interaction of health conditions at the level of the individual (body structure and function, activity, and participation) and contextual factors (personal and environmental) that promote function.[24,25] Developing an assessment tool that could identify adults with multimorbidity that are at risk for developing disability provides a health care provider the opportunity to initiate intervention prior to the onset of a functional limitation.[26] The measurement of grip strength has been investigated in order to best determine a grip strength cutoff value in order to predict future disability. The association between grip strength and self-report difficulty with upper extremity (UE) and lower extremity (LE) functional tasks has been previously reported with cutoff values ranging from 20–22 kg in females to 30–37 kg in males in order to predict those adults who will develop UE or LE disability in three separate studies completed outside of the U.S.[26-28]

Grip strength has been promoted as an overall measure of body strength.[10] A minimum amount of muscle strength is required for functional independence.[29] Adults with multimorbidity commonly have disability.[12] Adults with multimorbidity are commonly excluded from research.[22] Grip strength has been extensively investigated in a variety of populations; however, key gaps exist in the current literature with its relationship to multimorbidity and disability. Studies published on the topic of grip strength, multimorbidity, and disability may not be generalizable to the U.S. secondary to

differences in grip strength values, multimorbidity patterns, and functional limitations among countries.[30-32] Only one of the previous studies specifically investigated the role of multimorbidity on grip strength.[20] Grip strength normative and cutoff values, developed from a nationally representative sample, are not available for the large number of Americans with multimorbidity. The relationship among multimorbidity, grip strength, and the development of disability has yet to be fully investigated in a population-based study completed in the U.S. Further investigation of grip strength, multimorbidity, and disability may provide guidance to health care providers who monitor and manage an aging adult's health and functional status.

Conclusion

With increasing health care costs, the U.S. must look beyond the medical management of a single disease.[3,4] Single chronic diseases have been shown to negatively impact muscle strength.[14-19] Grip strength has been promoted as a measure of overall muscle strength and has strong psychometric properties.[9,10] Adults with chronic diseases are known to have more functional limitations than those without chronic diseases.[21] Predicting disability requires the consideration of multiple factors beyond the a single disease status, including weakness multimorbidity.[33] Early identification of adults with multimorbidity at risk for the development of disability would provide the opportunity for physical activity to be implemented into a patient's plan of care, potentially delaying the onset of disability.[29] Generalizability of current literature is limited due to differences in grip strength, multimorbidity, and disability among countries. An opportunity exists for

further investigation of the relationship among grip strength, multimorbidity, and disability in aging Americans utilizing a nationally representative sample.

Purpose of Research

The purpose of each of the following dissertation chapters is as follows:

Chapter 2: To investigate the relationship between the number of chronic diseases and common co-occurring chronic diseases and grip strength.

Chapter 3: To establish grip strength norms in U.S. adults age 50 years and older stratified by age, gender, and number of chronic diseases.

Chapter 4: To determine the optimal cutoff values and cutoff values with 75% sensitivity for grip strength based on multimorbidity to predict self-report UE and LE disability.

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CHAPTER 2

THE IMPACT OF MULTIMORBIDITY ON GRIP STRENGTH IN ADULTS AGE 50 YEARS AND OLDER

Introduction

The presence of two or more chronic conditions, also known as multimorbidity, is one of the most prevalent chronic conditions experienced by adults.[1] Currently, one in four American adults younger than age 65 and almost three in four adults aged 65 years and older have multimorbidity.[1,2] The presence of multimorbidity has been associated with increased risk of mortality and greater use of health care resources.[2-5] Twenty-five percent of adults with chronic diseases have one or more limitations in activity of daily living.[2]

Completing activities of daily living with ease requires the use of the hands and the ability to grip.[6,7] Grip strength is simple and affordable to measure, reliable, and may be used as a surrogate measure of overall muscle strength.[8-13] Grip strength has shown consistent relationships with gender and age.[13-19] At similar ages, males demonstrate stronger grip strength values than females.[13,14,16,17] Grip strength reaches a peak in adults from ages 30–50 years at which time it begins to slowly decline at a rate of 2% per year for both males and females.[15] Decreased grip strength has been found to be related to a lack of physical activity,[15] age-related changes to muscle fibers,[18] neural mechanisms,[18] and malnutrition[19] and predictive of premature mortality as well as the development of

disability.[8] Despite the fact that grip strength has been promoted as a vital sign, grip strength measurement is rarely used clinically in a physical assessment.[20-22]

The current literature demonstrates mixed evidence on the impact of specific single chronic diseases and grip strength without consideration for multimorbidity. Decreased grip strength has been associated in adults diagnosed with heart disease,[22-25] diabetes,[22-24,25,26] arthritis,[23,24,28,29] stroke,[23,30] prostate cancer,[31] and chronic obstructive pulmonary disease (COPD).[23,32] In contrast, increased grip strength has been reported in adults with diabetes,[33] COPD,[33] cardiovascular disease (CVD),[22] and hypertension (HTN).[24,28] Currently some evidence exists on the association of grip strength with the number of chronic diseases. In three studies, two completed in Europe and one completed in the U.S., multimorbidity explained a portion of decreased grip strength; however, age and muscle mass was responsible for a greater variance.[14,34,35] In a cross-sectional study of adults age 50 and older living in China, grip strength was found to be associated with multimorbidity in males and females. Males with two to eight chronic diseases had significantly lower grip strength *T*-scores than males with zero chronic diseases, while females without chronic diseases demonstrated significantly greater grip strength than females with four and seven chronic diseases.[36] While the current literature provides a foundation for the relationship of multimorbidity and grip strength, generalizability is limited. The study completed in the U.S. included a narrow age range of non-disabled adults age 70–79 years.[14] Differences in multimorbidity patterns and in grip strength have also been reported between different countries and ethnicities.[37,38] With the increasing number of adults with multimorbidity, further investigation of the effect of

multimorbidity on grip strength in a nationally representative sample of community-dwelling adults from the U.S. will add to the current evidence on the utilization of grip strength in clinical practice.

Multimorbidity is expected to impact 171 million Americans by 2030.[2] Providing care for patients with multimorbidity in a health care system that is designed to deliver and measure the success of care on the management of a single disease without the consideration of multimorbidity is challenging.[1,2] Grip strength has been promoted as a surrogate measure of overall muscle strength and recommended to be implemented into the physical examination of aging adults due to its predictive abilities and ease of use.[11] Current information available on the relationship between grip strength and multimorbidity is not necessarily generalizable to aging Americans who commonly have multimorbidity. Further understanding of the relationship of grip strength and multimorbidity would potentially prompt a health care provider to consider intervening in order to maintain or improve muscle strength and prevent the onset of disability in an adult with multimorbidity. The purpose of this paper is to investigate the relationship between the number of chronic diseases and common co-occurring chronic diseases and grip strength in a nationally representative data set collected in the U.S.

Methods

Data

Data utilized for this study were obtained from the 2008 wave of the Health and Retirement Study (HRS), a nationally representative biennial longitudinal study of U.S.

adults age 50 and older, completed by the University of Michigan Institute for Social Research and sponsored by the National Institute of Aging.[40] The HRS was designed to monitor the health and financial status of aging Americans.[41] The HRS has received approval from the Health Sciences Institutional Review Board at the University of Michigan. HRS is publicly available and does not contain any respondent identifiers. The current study was examined and considered exempt from the Institutional Review Boards at Western Michigan University and the University of Michigan-Flint.

In 2008, a total of 17,217 respondents were interviewed, while a subsample of 7,403 respondents were eligible for physical measurements. Respondents were excluded from final analysis if they did not provide consent for physical measures or had incomplete demographic information, leaving an unweighted sample size of 5,877 respondents representing 64.4 million U.S. adults age 50 years and older for analysis.

Variables and Their Measurement

Demographic Variables: Demographic variables of interest were age (50–59 years, 60–69 years, 70–79 years, and 80+ years), gender (male/female), and race (white, African American, other).

Anthropometric Measures: Height and weight measurements were taken following a standardized protocol by trained testers as a component of the physical measures section of the HRS.[42] The respondent was requested to stand (without shoes) against a wall and height was recorded to the nearest quarter inch. Weight was recorded using a Health o meter® 830KL scale (Sunbeam Products, Inc., Boca Raton, Florida) in all individuals who could stand and who self-reported weighing less than 300 pounds

(maximum weight measured with scale was 330 pounds). Weight was recorded to the nearest half pound. Height was converted to meters and weight to kilograms in order to calculate body mass index (kg/m^2) for respondents.

Chronic Diseases: Based on availability in the HRS data set as well as prevalence, morbidity, disability, and health care utilization, seven chronic diseases were selected for analysis from the self-reporting of the respondents' physical health and were coded as having been diagnosed (yes) or never been diagnosed (no). Respondents were asked whether a physician had ever told them that they had hypertension, diabetes or high blood sugar, arthritis or rheumatism, heart conditions (heart attack, myocardial infarction or congestive heart failure), lung disease, cancer, or stroke. Four groups were created by categorizing numbers of chronic diseases (0, 1, 2, ≥3).

Grip Strength: Grip strength was assessed using a Smedley's® spring-type hand dynamometer (Scandidact, Denmark).[42] The accuracy of the Smedley's® dynamometer to a known force has been shown to be high ($r = 0.98$) and has a strong association ($r = 0.83$) with the JAMAR® Hydraulic Hand dynamometer (Lafayette Instrument Company, Lafayette, Indiana).[9] Respondents were positioned in standing with the shoulder adducted and elbow flexed at 90°. If a respondent was unable to stand, he or she was allowed to sit and complete the test. A practice session was permitted and respondents were instructed to provide maximum effort for a couple of seconds and then release. Measurements were taken on each hand twice, starting with the dominant hand, alternating hands in between measurement trials. A maximum grip strength (kg) variable was created from all four

attempts and used as a continuous variable in analyses.[43] High agreement was exhibited among all four grip strength measurements (Cronbach's alpha = 0.979).

Analyses

The HRS was designed to differentially select for respondents so as to be nationally representative. To adjust for its complex sampling design, including the differential probability of selection and non-response, all analyses were weighted and adjusted using IBM® SPSS® Version 20 Complex Samples module (Armonk, New York). Standard descriptive statistics, including means, confidence intervals, and frequencies were calculated for age, race, chronic disease status, BMI, and maximum strength measurements. Multiple linear regression modeling was completed in order to examine the relationship between maximum grip strength and chronic disease status (specific diseases and number of chronic diseases) while adjusting for age and gender. The male gender, age group 50–59 years, and 0 chronic diseases served as referent values for their respective variables. A difference was considered statistically significant when $p < 0.05$.

Results

Table 2.1 shows selected characteristics of the study population, weighted to be nationally representative. The average age for the males was 65.9 years and 67.3 years for females. The mean number of chronic diseases for respondents was 1.9. Without consideration for number of chronic diseases, among the entire sample and in females, arthritis (58.5% and 66.1%) was the most prevalent disease; however, hypertension was

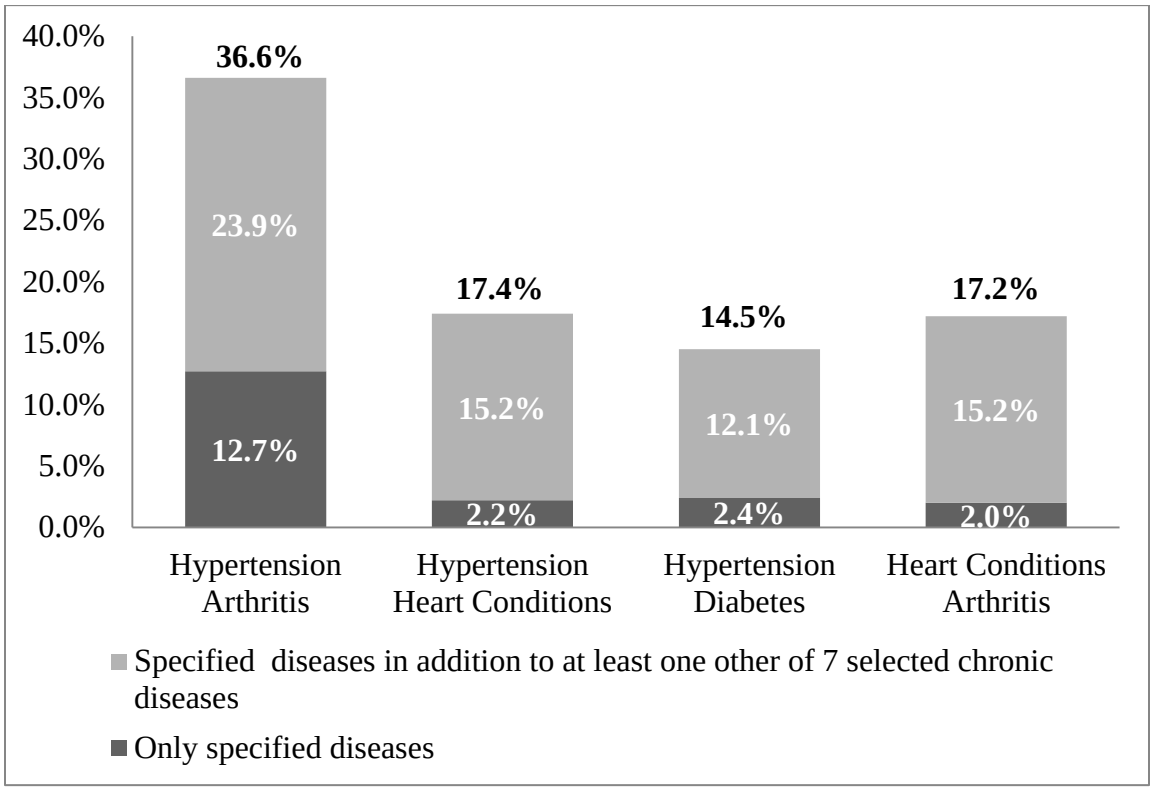
Table 2.1. Selected Respondent Characteristics

Characteristic	Overall sample (*n* = 5877) Mean (95% CI)	Males (*n* = 2774) Mean (95% CI)	Females (*n* = 3103) Mean (95% CI)
Age (years)	66.7 (66.3–67.1)	65.9 (65.3–66.4)	67.3 (66.9–67.8)
Body Mass Index (kg/m^2)	29.3 (29.1–29.6)	29.4 (29.1–29.6)	29.3 (28.9–29.7)
Number of chronic diseases (1–7)	1.9 (1.8–1.9)	1.85 (1.8–1.9)	1.90 (1.9–2.0)
Maximum Grip strength (kg)	33.1 (32.7–33.5)	42.1 (41.6–42.6)	25.1 (24.8–25.4)
	Weighted %	**Weighted %**	**Weighted %**
Race			
White	88.2	88.6	87.8
Black	8.8	8.0	9.6
Other	3.0	3.4	2.6
Body Mass Index Groups			
Underweight	0.8	0.4	1.1
Normal	22.9	17.8	27.5
Overweight	36.8	42.3	31.8
Obese	39.5	39.5	39.6
Chronic Diseases			
Hypertension	55.6	55.6	55.6
Diabetes	19.0	21.2	17.1
Cancer	14.1	14.1	14.0
Lung Disease	10.5	9.2	11.6
Heart Conditions	24.2	27.9	21.0
Stroke	5.9	6.9	5.0
Arthritis	58.5	50.0	66.1
Chronic Disease Groups			
Zero	15.7	17.4	14.2
One	26.6	26.6	26.6
Two	27.4	25.0	29.5
Three plus	30.3	31.0	29.7

Note. Weighted percentages and confidence intervals derived using the 2008 Health and Retirement Study (HRS) respondent population weights to adjust for the complex sampling design of the HRS survey.

the most common in males and second most common in females (males and females, 55.6%). In both males and females, heart conditions and diabetes mellitus were the third (males 27.9%, females 21.0%) and fourth (males 21.2%, females 17.1%) most prevalent

diseases, respectively. Over half of the respondents (57.7%) were considered to have multimorbidity. Hypertension and arthritis were the most prevalent combination for those with two diseases (12.7%) or those with three or more diseases (23.9%). Hypertension and heart conditions (17.4%), heart conditions and arthritis (17.2%), and hypertension and diabetes (14.5%) followed as the most prevalent disease combinations in adults with two or more chronic diseases (Figure 2.1).

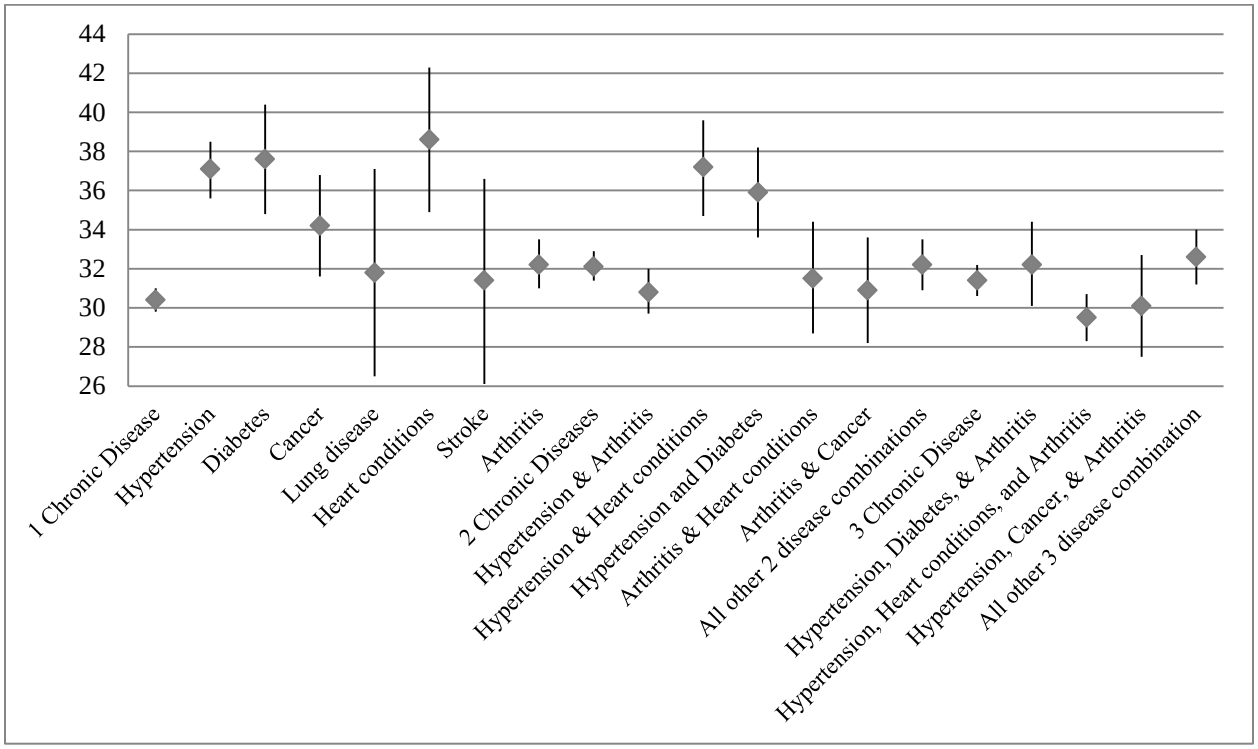


Note. All analyses completed using the 2008 Health and Retirement Study (HRS) respondent population weights to adjust for the complex sampling design of the HRS survey.

Figure 2.1. Frequency of the Four Most Common Combinations of the Seven Selected Chronic Diseases

The relationship of maximum grip strength, age, number of chronic diseases and specific chronic disease combinations is displayed in Figures 2.2–2.4. Figure 2.2 demonstrates the maximum grip strength by number of chronic diseases, as well as specific chronic diseases. In adults with one chronic disease, confidence intervals for adults with only lung disease and stroke demonstrated wide confidence intervals. As the number of diseases increased from two to three or greater, the means and confidence intervals began to cross each other. Based on these observations, further analysis (not shown) was completed on specific diseases. Crude analysis of all seven specific diseases (without consideration for number of diseases) placed into the model and adults with zero chronic diseases serving as the referent, demonstrated that cancer ($p = 0.005$), lung disease ($p = 0.002$), CVA ($p = 0.001$), arthritis ($p < 0.001$), and hypertension ($p = 0.004$) had a statistically significant association with grip strength, while heart conditions and diabetes were non-significant. When controlling for age and gender without consideration for number of diseases and adults with zero chronic diseases serving as the referent, diabetes ($p < 0.001$), lung disease ($p < 0.015$), heart conditions ($p < 0.012$), CVA ($p < 0.001$), and arthritis ($p = 0.001$) had a statistically significant association while cancer and hypertension were non-significant. When analyzing those respondents with only one chronic disease and using hypertension as the referent variable, those who had sustained a stroke ($b = –9.5$, 95% CI = –3.2, –15.7, $p = 0.004$) demonstrated a statistically significant relationship with maximum grip strength compared to those who did not have a stroke or arthritis but had one other chronic disease. In those respondents with two diseases (27%), when controlling for age and gender, the most frequent specific

combinations of diseases (hypertension and heart conditions, hypertension and diabetes, arthritis and heart conditions, arthritis and cancer) as well as all other two disease combinations did not demonstrate a statistically significantly different relationship with maximum grip strength compared to those with hypertension and arthritis, the referent category.

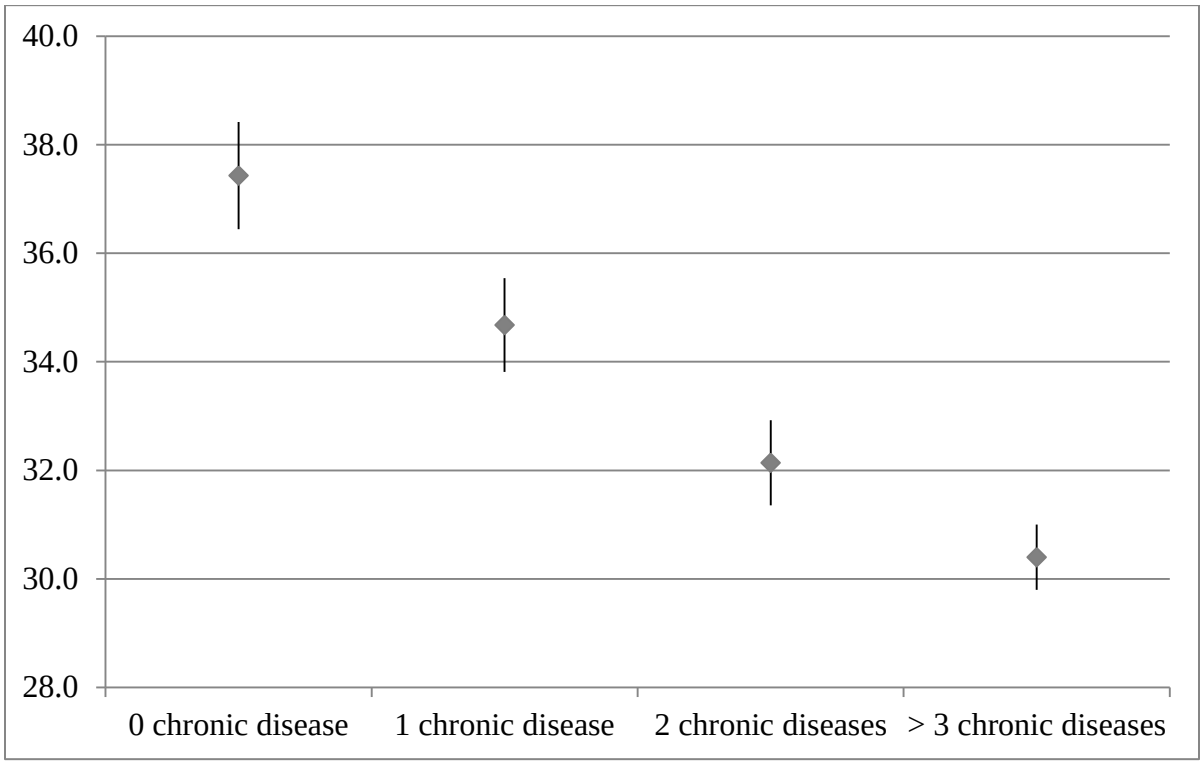


Note. All analyses completed using the 2008 Health and Retirement Study (HRS) respondent population weights to adjust for the complex sampling design of the HRS survey.

Figure 2.2. Maximum Grip Strength (kg) and 95% Confidence Intervals by Number of Chronic Diseases and Specific Combinations of Diseases

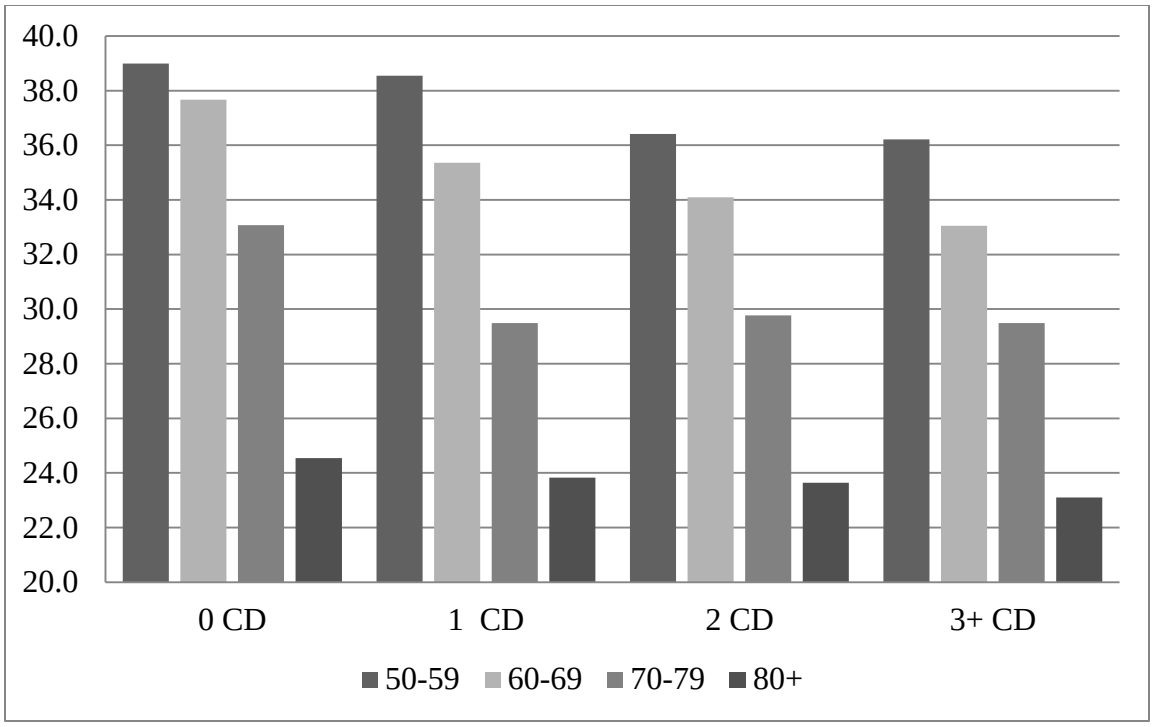
Figure 2.3 demonstrates a linear decrease in maximum grip strength based on the number of chronic diseases. Figure 2.4 demonstrates the decline in grip strength that

occurs across age groups within the same chronic disease group as well as a smaller decline across chronic diseases groups within the same age group. Based on these results, a multiple linear regression model was completed on maximum grip strength based on age, gender, and number of chronic diseases.



Note. All analyses completed using the 2008 Health and Retirement Study (HRS) respondent population weights to adjust for the complex sampling design of the HRS survey.

Figure 2.3. Maximum Grip Strength (kg) and 95% Confidence Intervals by Number of Chronic Diseases



Note. All analyses completed using the 2008 Health and Retirement Study (HRS) respondent population weights to adjust for the complex sampling design of the HRS survey.

Figure 2.4. Maximum Grip Strength (kg) by Age and Chronic Disease Status

Results reported in Table 2.2 demonstrated that gender, age (by decade), and chronic disease status (0, 1, 2, ≥3) significantly predicted maximum grip strength. Being female was associated with decreased grip strength (b = –16.4, 95% CI = –15.9, –16.9, $p < 0.001$). Maximum grip strength was inversely related to age, compared to respondents 50–59, those age 60–69 years (b = –2.5, 95% CI = –10.7, –12.3, $p < 0.001$), age 70–79 years (b = –6.5, 95% CI = –5.8, –7.2, $p < 0.001$), and respondents in the 80 plus group had decreased grip strength, with those 80 years or older having the largest decrease in grip strength (b = –11.5, 95% CI = –1.6, –3.3, $p < 0.001$). When controlling for age and gender, as the number of chronic diseases increased, grip strength decreased. Adults with

chronic disease demonstrated a step-like decrease in grip strength with each additional chronic disease; adults with one chronic disease (b = –0.9, 95% CI = –0.1, –0.7, p = 0.028), two chronic diseases (b = –1.6, 95% CI = –0.8, –2.3, $p < 0.001$), and in those adults with three or more diseases, the impact on grip strength was the largest (b = –3.1, 95% CI = –2.3, –3.9, $p < 0.001$).

Table 2.2. The Association of Maximum Grip Strength and Gender, Age, and Number of Chronic Diseases

Variable	Unstandardized Beta (95% CI)	*p*-value
Gender		
Male	Referent	
Female	–16.4 (–15.9, –16.9)	$p < 0.001$
Age		
50–59 years	Referent	
60–69 years	–2.5 (–1.6, –3.3)	$p < 0.001$
70–79 years	–6.5 (–5.8, –7.2)	$p < 0.001$
80 plus years	–11.5 (–10.7, –12.3)	$p < 0.001$
Chronic Diseases		
0 chronic disease	Referent	
1 chronic disease	–0.9 (–0.1, –1.7)	$p = 0.028$
2 chronic diseases	–1.6 (–0.8, –2.3)	$p < 0.001$
3+ chronic diseases	–3.1 (–2.3, –3.9)	$p < 0.001$
r^2 = 0.631		

Note. All analyses completed using multiple linear regression of the 2008 Health and Retirement Study (HRS) respondent population with weights to adjust for the complex sampling design of the HRS survey.

Discussion

In this cross-sectional study completed on a nationally representative sample of community-dwelling Americans age 50 and over, there was a statistically significant association between number of chronic diseases on grip strength independent of age and gender. As the number of chronic diseases increases, even when controlling for age and

gender, grip strength decreases, in particular in those adults with three or more chronic diseases. Consistent with previous literature, when accounting for specific diseases, without consideration for number of diseases and controlling for age and gender, diabetes, lung disease, heart conditions, CVA, and arthritis had a statistically negative association with grip strength.[22-32] When analyzing specific two-disease combinations' relationship with grip strength, no significant differences were found. The number of chronic diseases may serve as a proxy method of categorizing the relationship between disease and grip strength versus specific chronic diseases for clinicians managing the health care needs of the growing number of Americans with multimorbidity. The one exception from utilizing number of chronic diseases is for a person who has a history of a stroke with no other chronic diseases. In the current study, grip strength in the small number of respondents (1%) who reported having a stroke with no other chronic diseases demonstrated a large variability (X = 31.4 kg, 95% CI 26.1–36.6). Of the single chronic diseases selected for analysis, having a stroke is consistently associated with the motor deficit of hemiparesis and is the leading cause of adult long-term disability.[44]

The findings of the present study suggest that a non-disease specific physical performance measurement such as grip strength is well suited for use in individuals with multimorbidity, in addition to single disease measurements. For example, hemoglobin A1C, a diabetes test, reflects plasma glucose levels for the preceding 120 days, yet provides no information about the functional implications that an adult with diabetes may have or information about other chronic diseases that they may be co-concurrently managing.[45] A minimum amount of muscle strength is required for functional activities.[46]

Grip strength can be utilized as a measure of overall body strength.[47] In this study, multimorbidity was found to have a negative predictive relationship with grip strength. In order for older adults to function, the importance of muscle strength increases with age.[48] The additive impact of multimorbidity may lead to increase functional difficulty in older adults.[49] Adults with multimorbidity and functional limitations commonly spend more than two times on health care than those adults with multimorbidity and no limitations.[2] The current study supports the implementation of grip strength into the physical examination of the growing number of older adults who have multimorbidity.

Previous studies have reported that grip strength has relationships with other variables beyond multimorbidity. Grip strength has been shown to be impacted by age and gender. In the current study, consistent with previous work, males were consistently stronger than females and younger adults were stronger than older adults.[13-17] Body mass index has been reported to have no association, positive association, and a negative association with grip strength.[6,50] A relationship exists between increasing BMI and chronic diseases such as diabetes, hypertension, heart conditions, and arthritis.[51] BMI was intentionally left out of the regression analysis due to the potentially intervening relationship of BMI and chronic diseases on grip strength; therefore, the final model controlled for age, gender, and number of chronic diseases.

The sampling method of the HRS is intended to provide a representative view of the U.S. population. If considering only those HRS respondents age 65 and over, 71.5% would be considered to have multimorbidity, consistent with 73.1% previously reported.[2] Hypertension has been previously reported to be the leading chronic condition in adults

age 65 and over (60%), while, for the HRS 2008 data set, the most prevalent was arthritis at 68.8%; hypertension was second with 63.7%.[52] In a review of Medicare claims from 2002-2009, the most common two-disease combination was cardiovascular disease and arthritis, while the most common three-disease combination was cardiovascular disease, diabetes, and arthritis.[53] In comparison, the current study reported hypertension and arthritis as the most common two-disease combination, and hypertension, arthritis, and heart conditions as the most common three-disease combination. Challenges exist in comparing studies due to varying information collected on specific chronic diseases as well as various age ranges; however, the subsample used in this study is generally consistent in regard to prevalence of multimorbidity with previous work.

There are several considerations about the HRS dataset and the present analysis that must be discussed. Adults with multimorbidity present with varying number, combination, and severity of chronic diseases. It should be noted that the current study utilized information from seven chronic diseases and did not include any psychological diseases, such as anxiety or depression, which can also be chronic in nature. Other published studies have investigated a range of 5 to 39 chronic diseases when using disease counts as a method of multimorbidity.[54,55] Currently, there is not one accepted method of measuring multimorbidity, and in a recent systematic review investigating the measurement of multimorbidity, the most common method utilized was counting the number of chronic diseases.[54] Categorization of the chronic diseases in this study is consistent with other nationally representative studies, such as the National Health Interview Survey and the National Health and Nutrition Examination Survey.[53,55]

The self-reporting of chronic diseases has been found to have acceptable agreement as compared to objective confirmation of diagnosis.[56,57] Self-reporting also does not include undiagnosed conditions since respondents were specifically asked if a physician or other health care provider told them they had a particular chronic disease. Information collected on current chronic disease management and specific medications for each respondent is unknown in the HRS dataset, limiting the knowledge of current disease status. HRS respondents that did not provide consent or reported surgery, swelling, inflammation, severe pain, or injury in both hands in the past six months did not have grip strength measurements taken and were subsequently excluded from analysis.[42] Specific chronic diseases directly impacting the hand that may cause a person to be excluded from grip strength measurements include arthritis as well as a painful neuropathy potentially caused by diabetes. Based on the frequencies, respondents with both of these diseases consistently participated in grip strength measurements. The prevalence of diabetes and arthritis in the HRS subsample used in the current study were similar to other nationally representative studies.[58,59] Those excluded from analysis were more likely to have acute changes in grip strength caused by disease or trauma.

A primary strength of the current study is the utilization of a nationally representative data set that promotes an interdisciplinary investigation on the relationship of grip strength and multimorbidity; however, questions still remain. Future research opportunities include investigating the role of race, grip strength, and multimorbidity. For both males and females, African-Americans have been reported to have stronger grip strength than those that are white.[14] Rates of multimorbidity also differ between racial

and ethnic groups in the U.S., suggesting the need for sub-analysis by race/ethnicity.[60] The HRS is a longitudinal study; therefore, changes in grip strength and the relationship to multimorbidity over time could be analyzed. Development of normative grip strength for adults with chronic diseases from a nationally representative sample would allow a health care provider to compare current patient performance with norms developed from a similar population. Investigation of a grip strength cutoff value to predict disability in adults with multimorbidity would assist health care providers in prescribing and encouraging adults with multimorbidity to exercise in order to prevent or minimize the onset of disability.

Providing care for patients with multimorbidity has proven to be expensive, complex, and ineffective when care is provided within a single disease model.[1,2] The medical community is recognizing the need to consider management beyond pharmaceuticals when managing adults with multimorbidity, including the prescription of exercise.[61] Increasing physical activity is known to prevent and manage chronic diseases.[62] Incorporation of grip strength as a physical measure that can be used to monitor physical status over time may allow early identification of declining strength and promote a referral to a rehabilitation professional (e.g., physical therapist) who can design an individualized exercise program intended to maximize physical and functional capacity.[62]

Conclusion

Currently, close to three-fourths of Americans over the age of 65 have multimorbidity.[1,2] The current health care system is based on a single disease model.[1,2]

There has been a call to identify other measures that would provide information about the overall status of an individual with multimorbidity.[2] Grip strength is reliable and has demonstrated predictive abilities.[11] The current study demonstrated that as the number of chronic diseases increases, grip strength decreases, in particular, in those adults from the U.S. with three or more chronic diseases. Health care providers should consider implementing grip strength into clinical practice and consider the impact multimorbidity has on grip strength. Anticipation of changes in grip strength secondary to multimorbidity may prompt health care providers to consider the role exercise can play in the prevention and management of multimorbidity, as well as minimize physical decline and maximize function.

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CHAPTER 3

GRIP STRENGTH NORMS STRATIFIED BY AGE, GENDER, AND CHRONIC DISEASE STATUS IN ADULTS AGE 50 YEARS AND OLDER

Introduction

The maximum strength resulting from the collective contraction of intrinsic and extrinsic hand muscles which causes flexion of the fingers is commonly known as grip strength.[1] The ability to grip an object may be the most important function of the hand.[2] A person with impaired grip strength may have difficulty completing common activities of daily living that involve carrying, lifting, and manipulating objects.[2] Measuring grip strength with a hand-held dynamometer is simple, portable, affordable, and reliable.[3-8] Grip strength has been reported to be predictive of disability and mortality, as well as a surrogate measurement of overall muscle strength.[3-8]

One in four adults younger than age 65 and almost three in four adults aged 65 years and older have multiple chronic health conditions, also known as multimorbidity.[9,10] Americans with multiple chronic conditions now comprise over 25% of the population. As the population ages in the coming decades, the percentage of adults with multimorbidity is expected to increase.[9-11] In the United States (U.S.), 85% of health care dollars are spent on people with chronic conditions.[9] Multiple chronic health conditions negatively affect quality of life, contributing to declines in functioning and the inability to remain living in the community.[12] Utilization of the hands, including the ability to grip, is required to function effortlessly and independently. The current

literature provides evidence on the impact of single chronic diseases on grip strength without consideration for multimorbidity.[13,14] Chronic conditions such as coronary heart disease, cerebrovascular accident, chronic obstructive pulmonary disease, and diabetes mellitus have been found to be associated with decreased muscle strength, while hypertension has been found to be associated with increased grip strength.[13,14] The relationship between grip strength and multimorbidity has recently been investigated. In two separate studies, the number of chronic diseases had a negative relationship with grip strength; however, the relationship was small in comparison to age and body mass.[15,16] In a cross-sectional study of adults age 50 and older living in China, decreased grip strength was found to be associated with multimorbidity.[17] In Chapter 2 of this dissertation, multimorbidity was found to have a statistically significant negative association with grip strength.

Despite the relationship between grip strength and multimorbidity, there is currently a lack of grip strength norms, which serve as a reference point for the growing number of adults with multimorbidity. Clinically, grip strength norms are used to determine the presence and extent of weakness as well as to set rehabilitative goals for a patient.[18,19] Grip strength norms have been published in individual studies and meta-analyses. Current normative data published on grip strength are available for healthy adults,[1, 6,18-31] those with specific disabilities,[14] those with specific health conditions,[32-38] and different countries.[1,24,31] It has been recommended that samples for normative studies be large, random and representative of the population's heterogeneity.[19] Grip strength norms developed from other countries have been found to differ.[31,39] The majority of

published grip strength normative studies employ a convenience sample utilizing a relatively small number of subjects.[5,18,20,21] Research is needed to establish norms for a variety of diagnoses and age groups so appropriate benchmarks can be implemented in a variety of clinical circumstances.[19] Due to the increasing numbers of adults with multimorbidity and the lack of published grip strength norms utilizing data collected from a large nationally representative U.S. population, establishing grip strength norms based on the presence of multimorbidity may provide guidance to health care providers who monitor and manage an aging adult's health and functional status. The purpose of this study was to describe grip strength norms in adults 50 years and older in the U.S. based on age, gender, and number of chronic diseases on data collected from a nationally representative survey.

Methods

Data

Data from the University of Michigan Health and Retirement Study (HRS) were obtained for analysis. The HRS is a nationally representative biennial longitudinal study of adults over the age of 50 in the U.S.[40] The HRS is sponsored by the National Institute on Aging and conducted by the Institute for Social Research at the University of Michigan.[40] The Health Sciences Institutional Review Board at the University of Michigan approved the HRS.[40] The data used for the analyses are publicly available and contain no unique identifiers, ensuring respondent anonymity. The current study was

considered exempt by the Institutional Review Boards at Western Michigan University and University of Michigan-Flint.

A secondary data analysis was completed on HRS data collected in 2008, which included a total of 17,217 subjects of which 7,403 subjects were eligible for physical measurements, including grip strength. From that sample, respondents who did not provide consent or had incomplete demographics, chronic disease information, or physical measures were excluded from subsequent analyses. An unweighted sample size of 5,877 respondents, representing 64.4 million U.S. adults age 50 years and older, remained for analysis.

Variables and Their Measurement

Demographic Variables: Demographic variables of interest included age, gender (male/female), and race (white, African American, other). Based on previous publications of grip strength norms, age was further divided into four groups for analysis purposes (50–59 years, 60–69 years, 70–79 years, and ≥ 80 years).[6,20,21,24]

Chronic Diseases: A self-rating of respondents' physical health was assessed in HRS with respect to seven chronic medical conditions. Respondents were asked whether a physician had ever told them that they had hypertension, diabetes or high blood sugar, arthritis or rheumatism, heart conditions, lung disease, cancer, or stroke. Each chronic condition was coded as having been diagnosed (yes) or never been diagnosed (no). The seven chronic diseases chosen for analyses were selected based on prevalence, morbidity, disability, health care utilization, and availability in the HRS dataset.[9-11] The range of potential diseases for participants in the survey was from 0–7. Based on the results from

Chapter 2, four groups were created by categorizing numbers of chronic diseases (0, 1, 2, ≥3) and used in analysis.

Grip Strength: HRS trained testers collected grip strength measurements after the respondent provided consent and did not report surgery, swelling, inflammation, severe pain, or injury in both hands in the past six months.[41] The dynamometer used in the study was a Smedley's® spring-type hand dynamometer. The accuracy of the Smedley's® dynamometer to a known force has been shown to be high (r = 0.98) and a strong association (r = 0.83) with the JAMAR® Hydraulic Hand dynamometer (Lafayette Instrument Company, Lafayette, Indiana).[3] Respondents were positioned in standing with the shoulder adducted and elbow flexed to 90°. If a respondent was unable to stand, sitting was permitted to complete the test. Respondents were allowed to practice and were instructed to provide maximum effort for several seconds and then release. Measurements were taken on each hand twice, starting with the dominant hand, alternating hands between measurement trials. The average of the two trials was used to develop an average grip strength value for the right and the left hand measured in kilograms. The mean of two measurements of grip strength has been found to have acceptable test-retest reliability ($ICC_{2,1}$ = 0.96).[42] Mean grip strength, measured in kilograms (kg) was treated as continuous variable in subsequent analyses. All four grip strength measurements demonstrated high agreement (Cronbach's alpha = 0.979). In this study, grip strength was reported for the right and left hand, with no reference to hand dominance. Recent evidence indicates that hand dominance does not have influence on hand grip strength measurements or functional implications.[18,21,43]

Analyses

To adjust for the HRS complex sampling design, including the differential probability of selection and non-response, all analyses were weighted and adjusted using the IBM® SPSS® Version 20 Complex Samples module (Armonk, New York). Standard descriptive statistics, including means, 95% confidence intervals, and frequencies were calculated for age, gender, race, and chronic disease status. Grip strength means and confidence intervals were calculated and stratified by gender (male, female), age group (50–59 years, 60–69 years, 70–79 years, and ≥80 years), and number of chronic diseases (0, 1, 2, ≥3).

Results

Table 3.1 provides selected characteristics of the study population weighted to be nationally representative. Stratifying the sample by gender resulted in 2,442 males and 3,435 females. The average age for males was 65.9 years (95% CI 65.3–66.4) and for females was 67.3 years (95% CI 66.9–67.8). The mean number of chronic diseases was similar for males and females at 1.9 with 36.7% (n = 874) of the males and 33.5% (n = 1,078) of the females having three or more chronic diseases. Grip strength results were not presented by race as the majority of the sample was white (males 88.6% and females 87.8%), leaving a limited number of black and other respondents when stratified by age, gender, and chronic disease status.

Table 3.1. Selected Characteristics by Gender

Characteristics	Male (*n* = 2442) Mean (95% CI)	Female (*n* = 3435) Mean (95% CI)
Age (years)	65.9 (65.3–66.4)	67.34 (66.9–67.8)
Number of chronic diseases (0–7)	1.9 (1.8–1.9)	1.9 (1.9–2.0)
	% (*n*)	**% (*n*)**
Age Groups (Years)		
50–59	32.1 (784)	28.4 (976)
60–69	36.5 (891)	34.3 (1178)
70–79	20.9 (510)	22.1 (759)
≥ 80	10.5 (256)	15.1 (519)
Number of Chronic Diseases		
Zero	17.4 (321)	14.2 (349)
One	26.6 (547)	26.6 (813)
Two	25.0 (641)	29.5 (981)
Three or more	31.0 (874)	29.7 (1078)
Race		
White	88.6 (2039)	87.8 (2665)
Black	8.0 (273)	9.6 (475)
Other	3.4 (71)	2.6 (81)

Note. All analyses completed using the 2008 Health and Retirement Study (HRS) respondent population weights to adjust for the complex sampling design of the HRS survey.

Table 3.2 provides grip strength norms for the entire sample stratified by gender and age. Tables 3.3 and 3.4 provide grip strength norms by age and chronic disease groups in males and females. As demonstrated in previous studies, males are consistently stronger than females, and grip strength decreases with age.[18,20-31] Grip strength also demonstrated a decrease trend with increasing number of chronic diseases. The average male grip strength ranged from 46.8 kg (males 50–59 years with zero chronic diseases) to 28.1 kg (males 80 years and older with three or more chronic diseases). The average right

grip strength for females ranged from 27.5 kg (50–59 years with zero chronic diseases) to 16.8 kg (80 years and older with two chronic diseases).

Table 3.2. Mean Grip Strength (kg) in Males and Females by Decades

Age (years)	Males (*n* = 2442)		Females (*n* = 3435)	
	Left (95% CI)	Right (95% CI)	Left (95% CI)	Right (95% CI)
50–59	41.1 (40.2–42.0)	45.1 (44.2–46.1)	24.4 (23.9–25.0)	27.1 (26.5–27.6)
60–69	38.2 (37.3–39.0)	41.0 (40.1–42.0)	22.4 (22.0–22.8)	25.1 (24.7–25.5)
70–79	33.2 (32.6–33.8)	36.0 (35.3–36.6)	19.4 (19.0–19.8)	21.7 (21.2–22.1)
≥ 80	26.5 (25.8–27.3)	29.0 (28.0–30.0)	15.7 (15.3–16.1)	17.5 (17.0–18.0)

Note. All analyses completed using the 2008 Health and Retirement Study (HRS) respondent population weights to adjust for the complex sampling design of the HRS survey.

Discussion

Grip strength has been reported to be a reliable measure of overall muscle function and predictive of mortality and functional limitations.[5] Multimorbidity, in Chapter 2, demonstrated a negative association with grip strength. Approximately 75% of Americans over the age of 65 years have multimorbidity. Age and gender both have been previously listed as the strongest influencing factors on grip strength; however, disease severity and co-morbidities can also contribute to muscle weakness.[15,44,45] Using data from a cross-sectional, nationally representative U.S. study, the present study provides grip strength norms based on age, gender, and number of chronic diseases. The normative values calculated in this study in general demonstrate that as the number of chronic diseases increases, grip strength decreases.

Table 3.3. Mean Grip Strength (kg) in Males by Age and Number of Chronic Diseases

Age	% (*n*)	Males (*n* = 2442)	
		Left (95% CI)	Right (95% CI)
0 chronic diseases (17.4%, *n* = 425)			
50–59 years	51.6 (219)	42.7 (41.1–44.3)	46.8 (45.4–48.3)
60–69 years	36.6 (156)	40.0 (38.3–41.7)	43.1 (41.2–45.1)
70–79 years	8.3 (35)	36.4 (34.6–38.3)	38.8 (37.2–40.5)
≥ 80 years	3.5 (15)	26.3 (23.8–28.8)	27.6 (24.2–31.1)
1 chronic disease (26.6%, *n* = 650)			
50–59 years	44.2 (287)	41.3 (39.7–43.0)	45.7 (43.9–47.4)
60–69 years	35.8 (233)	38.9 (37.4–40.4)	42.1 (40.6–43.6)
70–79 years	14.4 (94)	34.0 (32.3–35.8)	37.2 (35.4–39.0)
≥ 80 years	5.6 (36)	29.2 (27.3–31.1)	31.4 (29.4–33.5)
2 chronic diseases (25.0%, *n* = 611)			
50–59 years	26.2 (160)	40.0 (38.1–42.0)	44.3 (42.0–46.6)
60–69 years	37.2 (227)	38.1 (36.7–39.6)	41.5 (39.4–43.5)
70–79 years	23.6 (144)	33.6 (32.5–34.6)	36.5 (35.3–37.6)
≥ 80 years	13.0 (79)	27.3 (25.8–28.8)	29.7 (27.9–31.5)
≥ 3 chronic diseases (31.0%, *n* = 757)			
50–59 years	15.5 (117)	39.0 (36.5–41.4)	41.8 (39.4–44.2)
60–69 years	36.4 (276)	36.5 (34.7–38.4)	38.6 (36.8–40.4)
70–79 years	31.2 (236)	32.2 (31.4–32.9)	34.8 (33.9–35.6)
≥ 80 years	16.8 (127)	25.3 (24.1–26.6)	28.1 (26.7–29.5)

Note. All analyses completed using the 2008 Health and Retirement Study (HRS) respondent population weights to adjust for the complex sampling design of the HRS survey.

Table 3.4. Mean Grip Strength (kg) in Females by Age and Number of Chronic Diseases

Age	% (*n*)	Females (*n* = 3435)	
		Left (95% CI)	Right (95% CI)
0 chronic diseases (14.2%, *n* = 488)			
50–59 years	53.4% (261)	24.9 (24.0–25.8)	27.5 (26.5–28.5)
60–69 years	32.9% (161)	24.0 (22.9–25.1)	27.2 (26.1–28.3)
70–79 years	8.9% (43)	21.0 (20.1–21.7)	23.5 (22.6–24.5)
≥ 80 years	4.7% (23)	16.9 (15.2–18.7)	19.0 (17.4–20.5)
1 chronic disease (26.6%, *n* = 914)			
50–59 years	37.1% (339)	25.0 (24.4–25.7)	27.5 (26.7–28.3)
60–69 years	32.2% (294)	22.6 (21.8–23.4)	25.2 (24.4–26.1)
70–79 years	20.2% (185)	19.9 (19.3–20.6)	22.1 (21.3–22.8)
≥ 80 years	10.5% (96)	16.2 (15.2–17.2)	18.2 (17.2–19.2)
2 chronic diseases (29.5%, *n* = 1013)			
50–59 years	24.3% (246)	24.3 (23.3–25.2)	26.9 (25.8–28.1)
60–69 years	36.3% (368)	22.9 (22.2–23.6)	25.4 (24.7–26.1)
70–79 years	23.9% (242)	20.0 (19.3–20.7)	22.1 (21.3–22.9)
≥ 80 years	15.5% (157)	15.2 (14.4–15.6)	16.8 (16.1–17.4)
≥ 3 chronic diseases (29.7%, *n* = 1020)			
50–59 years	12.9% (132)	22.5 (20.6–24.4)	25.5 (23.6–27.5)
60–69 years	34.8% (355)	21.2 (20.5–21.8)	23.9 (23.2–24.6)
70–79 years	28.5% (291)	18.4 (17.8–19.0)	20.7 (20.1–21.4)
≥ 80 years	23.8% (243)	15.7 (15.0–16.4)	17.6 (16.8–18.3)

*All analyses completed using the 2008 Health and Retirement Study (HRS) respondent population weights to adjust for the complex sampling design of the HRS survey.

Grip strength in adults begins to decline at a rate of 1% per year after middle age.[13] The results of this study demonstrate grip strength decreases with aging. Males consistently are stronger than females. The results of this study demonstrate that males over the age of 80 years (right grip = 29.0 kg) are still stronger than females who are age 50–59 years (right grip = 27.1 kg). Consistent with previous research, the right hand for both males and females was stronger than the left hand.[18]

Challenges exist in directly comparing grip strength norms secondary to differences in protocols, dynamometers, sampling procedures, and populations. Although reference values for grip strength have been published previously, the majority of studies utilized convenience sampling with a limited number of participants, which may produce inflated estimates of normative values.[5, 18, 20-21] Desrosiers et al[18] grip strength norms reported on *n* = 360 adults from Canada were consistently higher than in the current study; however, Mathiowetz et al[20] demonstrated variable differences between gender and age groups as compared to the current study. Two recent meta-analyses on grip strength in older adults generally demonstrate wider confidence intervals as compared to the current study.[46,47] Interpretation of meta-analysis data should be cautiously completed due to the heterogeneity between studies.[48] Both meta-analyses reported lower grip strength values when compared to the present study in adults matched by age and zero chronic diseases. The results of the current study, when including the entire sample and stratified by age and gender only with no consideration for multimorbidity, were comparable to the meta-analyses with no norms different than 5 kg for males and 3 kg for females. Grip strength has been found to differ between countries. Grip strength norms

developed in a population-based study in Australia were generally lower in adults over the age of 60 years as compared to the adults in the current study with zero chronic diseases; however, when including the entire sample without consideration for multimorbidity, there was no more than a 2 kg difference between age and gender.[24] Norms developed in Canada were greater in males (range 4–7 kg) as compared to males in the current study; however, the females in Canada demonstrated greater variability when compared to U.S. females (ranging from American females being 3 kg weaker to being 3 kg stronger based on age group).[20] Neither of these studies reported the presence or absence of chronic diseases in the sample.[20,28] As published elsewhere, grip strength norms based from an American sample were larger than that collected from one of Asian descent.[39] Based on the result of these studies and the difference between dynamometers utilized, grip strength values among age matched American adults, without any consideration for multimorbidity, and Australians and Canadians are similar.

Grip strength measured at one point in time has been shown to predict declines in mobility.[49] A minimum amount of strength is required to complete functional activities.[50] Grip strength is easy to measure, cost-effective, reliable, and predictive.[8] Despite the clinical utility, grip strength is rarely implemented into practice.[50] Providing grip strength norms for clinicians allows a measurement beyond single disease to track an adult's physical performance over time. If a patient begins to fall below what is considered appropriate for his or her age and gender, as well as number of chronic diseases, a clinician should consider intervening with a physical activity and/or exercise program. An increase in physical activity has been shown to increase strength, promote function,

and manage the effects of chronic diseases.[51] Patients are commonly aware of single disease assessments that allow them to track their health status (e.g., blood glucose levels). Aging adults may also consider self-monitoring their grip strength and track changes over time. Objectively quantifying grip strength, an overall measure of muscle function, may provide motivation to maintain and/or increase strength.

The present study is not without limitations. The state of disease management and specific medications for each of the respondents were unknown. It has been reported that the use of some cardiovascular medications is associated with decreased grip strength in older adults.[52] The current study employed a cross-sectional analysis and does not imply causality of decreased grip strength due to the presence of chronic diseases. By stratifying the data by age, gender, and number of chronic diseases, there was a wide range of respondents in each category. The sample of respondents ranged from females age 60–69 years with two chronic diseases (n = 368) to males over the age of 80 years with zero chronic diseases (n = 15). The JAMAR® hand dynamometer has been utilized frequently in studies publishing grip strength norms; however, no consensus exists on what type of dynamometer should be utilized.[21] Different models of dynamometers (e.g., Smedley's®) have been used in research and are useful in the development of grip strength norms.[53] Grip strength norms developed on different types of instruments have been reported to not be interchangeable; however, the Smedley's® dynamometer has been found to have a strong association with the JAMAR® (r = 0.83).[3,53] A standardized testing protocol and position is important for reliability and to compare results across normative studies; however, wide ranges of protocols and positions have been developed for grip strength

testing.[54] Commonly, studies utilize standards promoted by the American Society of Hand Therapists (ASHT), including the recommendation that patients sit during grip strength testing.[54] The HRS protocol called for patients to stand for measurements and sit if unable to stand.[41] Standing during hand grip strength testing has been shown to produce higher strength values than when sitting.[55]

A key strength of this study is the use of HRS data. The HRS is a nationally representative survey and includes self-report information on chronic diseases as well as physical measures collected utilizing standardized methods and trained testers. The agreement between the self-report of a diagnosis and confirmed evidence of diagnosis has been found to be excellent for diabetes mellitus (Kappa 0.92–0.93), cancer (Kappa 0.72–0.90), and stroke (Kappa 0.81–0.85) and good to fair for angina (Kappa 0.73–0.57), congestive heart failure (Kappa 0.48), and myocardial infarction (Kappa 0.47–0.70) in two separate studies.[56,57] The development of normative data utilizing a nationally representative dataset improves its generalizability to the population. Stratifying the data by gender, age, and number of chronic diseases provided a novel method in developing grip strength norms, and considering the prevalence of multiple chronic diseases in Americans, offers a different, yet important standard which clinicians and researchers can implement in practice. Since the HRS is completed every two years, future research could examine the longitudinal changes that occur with grip strength and the presence of chronic diseases over time. Further research could also be completed in order to investigate the potential combination of most prevalent combinations of multimorbidities and the impact on grip strength as well as the utilization of grip strength cutoff values to

predict disability in adults with multimorbidity. Further investigation of the barriers, outcomes, and utilization of grip strength norms into the management of patients with multimorbidity may assist in increasing the acceptance of grip strength into in clinical practice.

Conclusion

The most prevalent chronic condition of aging Americans is multimorbidity.[9,10] Multimorbidity is associated with decreased strength and disability.[12] Grip strength norms are commonly developed on healthy adults from a convenience sample. Adults with multimorbidity are commonly excluded from research studies.[58] Normative data for grip strength on adults based on age, gender, and number of chronic diseases can be compared to evaluate performance of older adults who commonly have a history of multiple chronic conditions. Data provided for the study were from a nationally representative sample, improving its generalizability to a growing population with multimorbidity that requires health care services. Clinicians should consider incorporating grip strength into a comprehensive physical assessment and consider prescribing exercise or referring a patient for rehabilitation services if there are declines in hand grip strength that fall below anticipated norms.

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CHAPTER 4

GRIP STRENGTH CUTOFF VALUES IN ADULTS WITH MULTIMORBIDITY

Introduction

Improving the health, function, and quality of life of older adults is a public health priority.[1] Twenty-eight percent of all Americans have two or more chronic diseases, also known as multimorbidity.[2] Approximately 25% of people with chronic diseases have one or more daily activity limitations.[2] Adults with chronic conditions and functional limitations spend three times as much on health care as compared to adults with chronic condition(s) and no functional limitations.[3] The current health care system is in need of patient-centered measurements that are beyond a single disease and consider the implications of multimorbidity, including the increased incidence of disability.[2]

Developing an assessment tool that would identify adults who are at risk for developing disability provides an opportunity for an intervention, such as physical activity, to be initiated prior to the onset of a functional limitation.[4] Muscle strength has been promoted as the single best measure of age-related muscle change and is associated with functional limitations.[5,6] Grip strength is an indicator of overall muscle strength and is representative of a person's overall health.[7,8] Decreased grip strength has been associated with an increased risk of upper extremity disability,[4] mobility disability,[9,10] instrumental activities of daily living (IADLs) limitations,[10,11] activities of daily living (ADLs) limitations,[5] and multimorbidity.[12] A range of 9 to 20 kilograms (kg) of grip

strength has been published as the amount of grip strength required to complete most activities of daily living.[10,13,14]

Self-report measures of disability are widely utilized in the clinical and research settings and can be used to categorize older adults into the stages of functional decline.[15] As adults age, difficulties with mobility emerge first, followed by IADLs, and lastly difficulties with ADLs.[16] The association between grip strength and self-report difficulty with upper extremity (UE) and lower extremity (LE) functional tasks and grip strength has been investigated in order to best determine a grip strength cutoff value in order to predict future disability. In a study completed on a convenience sample of 469 older adults in Taiwan, the cutoff grip strength values to discriminate between able and disabled groups for performing heavy tasks with the UE with 75% sensitivity (specificity not provided) were 34 kg for males and 22 kg for females.[4] Grip strength cutoff points have also been found to predict mobility limitations, primarily thought to be caused from lower extremity dysfunction. Laurenti et al[17] in 2003, utilizing a nationally representative data set of adults age 20–102 years from Italy, determined cutoff values (sensitivity and specificity not provided) of 30 kg in males and 20 kg in females as the threshold that best discriminates subjects with mobility limitations. Using cross-sectional data from a Finland-based population survey of adults age 55 years and older, Sallinen et al[18] in 2010 determined the cutoff values for the likelihood of mobility limitation were 37 kg (sensitivity 73%; specificity 79%) for males and 21 kg (sensitivity 67%; specificity 73%) for females.

The previously mentioned studies provide a foundation of grip strength cutoffs and may not be generalizable to the population in the U.S. based on reported differences in grip strength, multimorbidity patterns, and functional limitations between countries.[19-21] In addition, none of the previously mentioned studies investigated the role of multimorbidity on cutoff grip strength values to predict UE and/or LE disability. The purpose of this paper was to determine the optimal cutoff values and cutoff values with 75% sensitivity for grip strength based on multimorbidity to predict self-reported UE and LE disability.

Methods

Data

The 2008 wave of the Health and Retirement Study (HRS) was analyzed for this study. Sponsored by the National Institute of Aging, completed by the University of Michigan Institute for Social Research, and launched in 1992, the HRS is a nationally representative biennial longitudinal study of U.S. adults age 50 and older.[22] The HRS has received approval from the Health Sciences Institutional Review Board at the University of Michigan. HRS data has no identifiers and is publicly available; therefore, the current study was considered exempt by the Institutional Review Boards at Western Michigan University and the University of Michigan-Flint.

In 2008, a total of 17,217 respondents were interviewed, while a subsample of 7,403 respondents was eligible for physical measurements, including grip strength. Respondents were excluded from final analysis if they did not provide consent for

physical measures or had incomplete demographic information. An unweighted sample size of 5,877 participants representing 64.4 million U.S. adults age 50 years and older was used for analysis.

Variables and Their Measurement

Demographic Variables: Demographic variables of interest were age (years), gender (male/female), and race (white, African American, other).

Anthropometric Measures: Height and weight measures were taken following a standardized protocol as a component of the physical measures section of the HRS and have been described elsewhere.[23] Height was converted to meters and weight to kilograms in order to calculate body mass index (BMI, kg/m^2) for respondents.

Chronic Diseases: Respondents were asked whether a physician had ever told them that they had hypertension, diabetes or high blood sugar, arthritis or rheumatism, heart conditions (heart attack, myocardial infarction or congestive heart failure), lung disease, cancer, or stroke. Based on the self-report, the seven chronic diseases selected were coded as having been diagnosed (yes) or never been diagnosed (no). Four groups were created by categorizing the total number of chronic diseases (0, 1, 2, ≥3) self-reported by respondents.

Self-Report Disability: Respondents were asked if they had any difficulty lifting ten pounds (defined as UE disability) and difficulty in ambulating several blocks (defined as LE disability). Responses were coded as having difficulty (yes) or not having difficulty (no). Respondents who reported they "can't do" or "don't do" were coded as having difficulty.

Grip Strength: Grip strength was assessed using a Smedley's® spring-type hand dynamometer (Scandidact, Denmark).[23] Respondents were positioned in standing with the shoulder adducted and elbow flexed to 90°. If a respondent was unable to stand, he or she was allowed to sit and complete the test. Respondents were instructed to provide maximum effort for a couple of seconds and then release. A practice session was allowed, and measurements were taken on each hand twice, starting with the dominant hand, alternating hands in between trials. A maximum grip strength (kg) variable was created from all four attempts and used as a continuous variable in analyses.[40] High agreement was exhibited among all four grip strength measurements (Cronbach's alpha = 0.979).

Analyses

Respondent characteristics including age, gender, race, BMI, chronic disease status, and functional limitations were calculated. Receiver Operating Characteristic (ROC) curves were created in order to determine the relationship of grip strength in determining the sensitivity (positive result when the disability is present) and specificity (negative result when disability is not present).[24] The ROC curves were used to determine the optimum cutoff value for grip strength to predict UE or LE disability with the minimum value produced utilizing the formula $(1\text{-sensitivity})^2 + (1\text{-specificity})^2$.[25] A cutoff value of 75% sensitivity was also selected as a secondary cutoff value. The intention of setting a sensitivity of 75% to determine cutoffs was to increase the opportunity to identify those adults at risk for developing an UE or LE disability in order to prompt a clinician to offer an intervention such as exercise. The consequences of a false positive result, that is the identification of a person at risk who was not at risk,

would be negligible since the intervention would potentially involve an increase of physical activity. An alpha value of 0.05 was determined for statistical significance. All analyses were performed using IBM® SPSS® Version 20 (Armonk, New York). Descriptive statistics for the sample were completed with the Complex Samples module in order to account for the complex sampling design utilized to create the HRS sample. Currently, SPSS is unable to calculate ROC curves while taking into account complex sampling; therefore, ROC curves were completed using standardized statistical procedures.

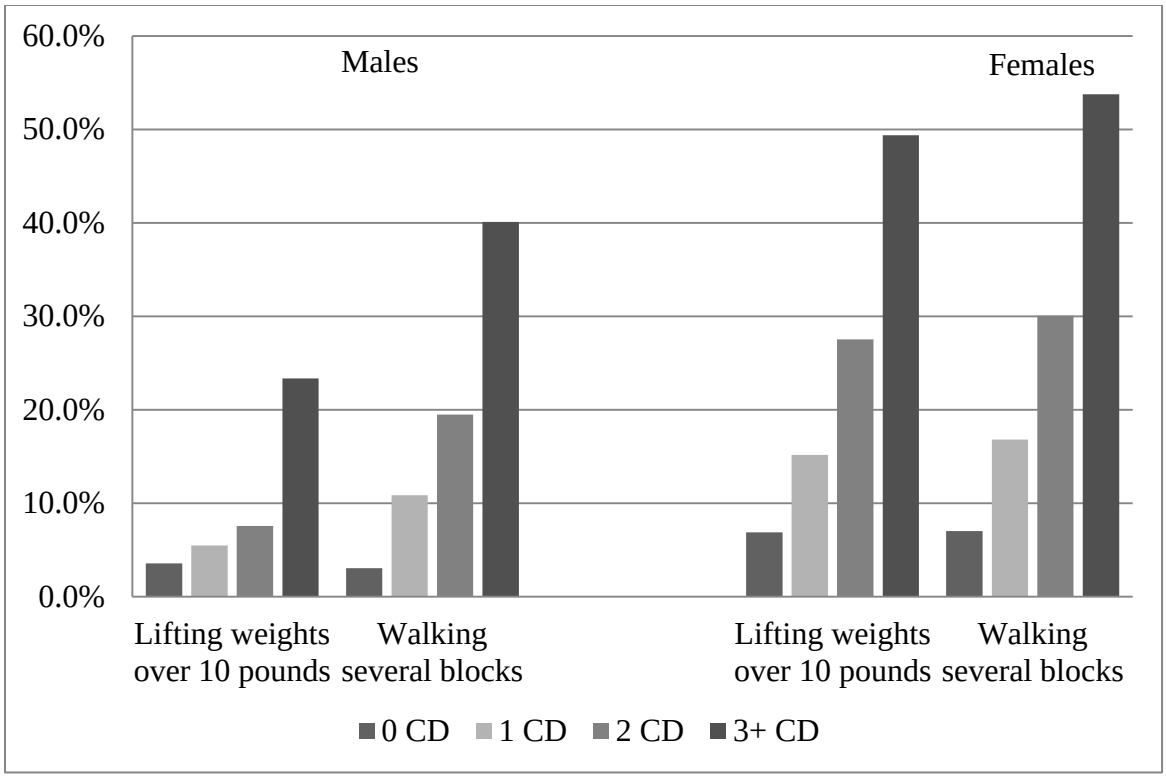
Results

Table 4.1 demonstrates characteristics of the study sample. The study included 2,442 males (41.6%) and 3,435 females (58.4%). The average age for males was 65.9 years and for females was 67.3 years. The sample was primarily white (males, 88.6%; females, 87.8%). BMI for both males and females was 29 kg/m^2, which is considered overweight. On average, both males and females had 1.9 chronic diseases. When comparing adults with and without the report of UE disability or LE disability, those males and females with functional limitations had 1.1 more chronic diseases as compared to those without functional limitations. Females demonstrated increased prevalence of UE and LE disability (39.8%) as compared to males (23.9%). As the number of chronic diseases (CDs) increased in both males and females, frequency of self-report UE and LE disability increased (Figure 4.1).

Table 4.1. Selected Characteristics of Health and Retirement Study 2008 Participants Stratified by Gender and Disability Status (*n* = 5,877)

	Male Mean (95% CI) % (*n*)			Female Mean (95% CI) % (*n*)		
	All (*n*=2442)	No disability (*n*=1858)	UE and/or LE disability (*n*=584)	All (*n*=3435)	No disability (*n*=2068)	UE and/or LE disability (*n*=1367)
Age (years)	65.9 (65.3-66.4)	64.7 (64.2-65.3)	69.5 (68.5-70.4)	67.3 (66.9-67.9)	65.2 (64.8-65.6)	70.6 (69.9-71.3)
Number of chronic diseases (0-7)	1.9 (1.8-1.9)	1.6 (1.5-1.7)	2.7 (2.6-2.9)	1.9 (1.9-2.0)	1.5 (1.4-1.5)	2.6 (2.5-2.7)
Body Mass Index (kg/m^2)	29.4 (29.1-29.6)	29.2 (28.9-29.4)	30.1 (29.5-30.7)	29.3 (28.9-29.7)	28.4 (28.0-28.7)	30.7 (30.2-31.2)
Grip strength (kg)	42.1 (41.6-42.6)	43.6 (43.1-44.2)	37.1 (36.0-38.1)	25.1 (24.8-25.4)	26.8 (26.5-27.1)	22.6 (22.2-23.0)
Number of Chronic Diseases						
Zero	17.4% (321)	21.7% (403)	3.6% (21)	14.2% (349)	21.0% (434)	3.9% (53)
One	26.6% (547)	30.3% (563)	14.6% (85)	26.6% (813)	33.5% (693)	16.2% (221)
Two	25.0% (641)	25.4% (472)	23.7% (138)	29.5% (981)	28.6% (591)	30.9% (422)
Three or more	31.0% (874)	22.5% (418)	58.1% (339)	29.7% (1078)	16.9% (349)	49.1% (671)
Race						
White	88.6% (2039)	88.7% (1648)	88.2% (515)	87.8% (2665)	89.4% (1849)	85.2% (1165)
Black	8.0% (273)	8.0% (149)	7.9% (46)	9.6% (475)	8.5% (176)	11.2% (153)
Other	3.4% (71)	3.3% (61)	3.9% (23)	2.6% (81)	2.1% (43)	3.5% (48)

Note. All analyses completed using the 2008 Health and Retirement Study (HRS) respondent population weights to adjust for the complex sampling design of the HRS survey.



Note. All analyses completed using the 2008 Health and Retirement Study (HRS) respondent population weights to adjust for the complex sampling design of the HRS survey.

Figure 4.1. Frequency of Self-Report Difficulty Lifting Over 10 Pounds (UE Disability) and Walking Several Blocks (LE Disability) by Gender and Number of Chronic Diseases (*n* = 5877)

The ability of grip strength to accurately discriminate between adults with and without UE and/or LE disability is reflected by the area under the curve (AUC) of the ROC curve analysis. Based on the results, grip strength shows moderate accuracy (AUC = 0.7) for predicting UE and LE disability for the entire sample of males and females, and was statistically significant ($p < 0.001$).[25] Discriminative ability (AUC) and the optimum and 75% sensitivity cutoff values for the entire sample, without consideration of multimorbidity, are listed in Table 4.2. Including the entire sample,

males demonstrated cutoff values respectively of 35.3 kg (58% sensitivity, 72% specificity) and 37.8 kg (sensitivity 62%, specificity 67%) in self-report of UE and LE disability. The entire sample of females demonstrated cutoff values of 22.3 kg (57% sensitivity, 73% specificity) and 23.3 kg (59% sensitivity, 67% specificity), respectively, in self-report of UE and LE disability.

Table 4.2. Grip Strength Cutoff Value for Males and Females With Self-Report Difficulty Lifting 10 Pounds and Difficulty Walking Several Blocks

Sample	AUC (95% CI)	*p*-value	Cutoff (kg)	Sensitivity (%)	Specificity (%)	Cutoff with (kg) 75% sensitivity	Specificity (%)
Difficulty Lifting 10 Pounds							
Males	0.70 (0.67-0.74)	$p<0.001$	35.3	58	72	40.3	52
Females	0.69 (0.67-0.71)	$p<0.001$	22.3	57	73	26.3	46
Difficulty Walking Several Blocks							
Males	0.68 (0.66-0.71)	$p<0.001$	37.8	62	67	41.8	49
Females	0.67 (0.65-0.69)	$p<0.001$	23.3	59	67	26.3	46

When reviewing the data by number of CDs, the AUC ranged between 0.6–0.7 (low to moderate accuracy) in both males and females[25] (see Table 4.3). In general, as the number of CDs increases, the cutoff decreases, in particular between adults with 0 CD and those with ≥3 CDs. For the self-report of UE disability, in males with 0 CD, the optimum cutoff was 41.3 kg (69% sensitivity and 68% specificity), while males with ≥3 CDs demonstrated an optimum cutoff of 36.3 kg (70% sensitivity and 60% specificity)**.** In females with 0 CD, the optimum cutoff for self-report of UE disability was 23.3 kg (53% sensitivity and 79% specificity), while females with ≥3 CDs demonstrated an optimum cutoff of 21.8 kg (58% sensitivity and 65% specificity). For the self-report LE

Table 4.3. Grip Strength Cutoff Value Based on Number of Chronic Conditions for Males and Females With Self-Report Difficulty Lifting 10 Pounds and Difficulty Walking Several Blocks

Sample	AUC (95% CI)	*p*-value	Cutoff (kg)	Sensitivity (%)	Specificity (%)	Cutoff with (kg) 75% sensitivity	Specificity (%)
Difficulty Lifting 10 Pounds							
Males							
0 chronic disease	0.72 (0.59-0.85)	*p*=0.003	41.3	69	68	44.3	50
1 chronic disease	0.65 (0.54-0.75)	*p*=0.003	37.3	56	70	45.3	40
2 chronic diseases	0.64 (0.56-0.72)	*p*<0.001	37.8	62	61	41.8	43
≥3 chronic diseases	0.69 (0.65-0.73)	*p*<0.001	36.3	70	60	38.3	52
Females							
0 chronic disease	0.72 (0.64-0.81)	*p*<0.001	23.3	53	79	27.3	50
1 chronic disease	0.68 (0.63-0.73)	*p*<0.001	23.3	57	71	26.8	47
2 chronic diseases	0.64 (0.60-0.68)	*p*<0.001	23.3	58	66	26.8	44
≥3 chronic diseases	0.66 (0.62-0.69)	*p*<0.001	21.8	58	65	25.3	40
Difficulty Walking Several Blocks							
Males							
0 chronic disease	0.71 (0.55-0.87)	*p*=0.001	41.3	69	68	42.8	60
1 chronic disease	0.67 (0.60-0.74)	*p*<0.001	37.3	60	73	45.3	41
2 chronic diseases	0.61 (0.56-0.67)	*p*<0.001	37.8	56	63	42.3	40
≥3 chronic diseases	0.64 (0.60-0.68)	*p*<0.001	36.8	61	61	40.3	43
Females							
0 chronic disease	0.68 (0.59-0.78)	*p*=0.001	25.3	61	62	27.3	49
1 chronic disease	0.69 (0.64-0.74)	*p*<0.001	23.3	59	71	26.3	50
2 chronic diseases	0.60 (0.56-0.64)	*p*<0.001	24.8	58	57	27.8	36
≥3 chronic diseases	0.63 (0.60-0.67)	*p*<0.001	21.8	55	65	25.3	40

disability, males with 0 CD demonstrated an optimum cutoff 41.3 kg (69% sensitivity and 68% specificity), while males with ≥3 CDs demonstrated an optimum cutoff of 36.8 kg (61% sensitivity and 61% specificity)**.** Females with 0 CD demonstrated a cutoff 25.3 kg (61% sensitivity and 62% specificity), while females with ≥3 CDs demonstrate a cutoff of 21.8 kg (55% sensitivity and 65% specificity). In summary, males with 0 CD demonstrated an optimal cutoff value of 41.3 kg whether determining UE or LE disability, while 36.3 kg and 36.8 kg were the respective cutoff values in males with ≥3 CD. In females with 0 CD, the cutoff values for determining UE or LE disability were 23.3 kg and 25.3 kg, respectively, while the cutoff for determining UE or LE disability in females with ≥3 CDs was 21.8 kg.

In pre-determining a sensitivity of 75% in order to maximize the ability to identify those at risk for developing disability, grip strength cutoff values increased across gender and chronic disease status as compared to the optimal cutoff values that were determined; however, a similar pattern of decreasing cutoff values were observed based on chronic disease status. Using a cutoff value of 75% sensitivity, the entire sample of males, without consideration for number of chronic diseases, demonstrated cutoff values of 40.3 kg (52% specificity) and 41.8 kg (49% specificity) for respectively determining UE and LE disability. In females, the cutoff value with 75% sensitivity was 27.3 kg (46% specificity) for both UE and LE disability. When considering the number of chronic diseases and utilizing 75% sensitivity, male cutoff values for grip strength ranged from 44.3 kg (50% specificity) in males with 0 CD to 38.3 kg (52% specificity) in males with ≥3 CD in predicting UE disability and 42.8 kg (60% specificity) in males with 0 CD

to 40.3 kg (43% specificity) in males with ≥3 CD to predict LE disability. Correspondingly for females, 75% sensitivity cutoff values for grip strength ranged from 27.3 kg with 0 CD to 25.3 kg with ≥3 CD in predicting UE and LE disability (specificity ranging from 30%–50%). In summary, when optimizing sensitivity and specificity values, males without multimorbidity and a grip strength <41 kilograms and males with multimorbidity and a grip strength of <36 kg would be anticipated to develop UE and LE disability. Females without multimorbidity and a grip strength of <25 kg and females with multimorbidity and a grip strength of <21 kilograms would be anticipated to develop UE and LE disability. When setting the sensitivity to 75%, the grip strength values including the entire sample of males <40 kg and <26 kg in females would be anticipated to predict UE and LE disability.

Discussion

The purpose of this study was to determine the optimal cutoff values and cutoff values for 75% sensitivity for grip strength based on multimorbidity in order to predict self-report upper extremity and lower extremity disability in community-dwelling adults over the age of 50 in the U.S. The relationship between muscle strength, disability, and multimorbidity is complex. Disability is known to increase with older age.[26] The number of chronic diseases has been found to predict the risk of mobility and ADL disability.[27,28] Older adults have decreased grip strength.[17] Adults over the age of 65 who are obese are more likely to have greater risk of disability.[29] Consistent with these previously published findings, respondents in the current study with either the report of an UE or LE disability on average were older, had >2 chronic diseases, decreased grip strength, and would be

categorized as obese. Adults with multimorbidity demonstrate lower grip strength cutoff values than those adults without multimorbidity when using optimal cutoffs or cutoffs with 75% sensitivity. Consistently, those adults with ≥3 CDs demonstrated a lower cut off value than all other groups. In particular, those adults with ≥3 CDs demonstrated very similar cutoff values whether determining UE or LE disability in both males (36.3 kg, UE disability; 36.8 kg, LE disability) and females (21.8 kg, UE and LE disability).

As adults age, difficulties in mobility are commonly the first report of functional disability, followed by IADLs and ADLs.[16] The results of this study demonstrated similar cutoff values for determining UE or LE disability, with the largest difference being 2.5 kg between the UE disability (35.3 kg) and the LE disability (37.8 kg) cutoff values. When considering multimorbidity, grip strength cutoff values were less in adults with multimorbidity as compared to those adults with multimorbidity. Increased health care costs are associated with adults with chronic diseases and disability.[3] Early identification of adults with multimorbidity at risk for disability would prompt a health care provider to provide timely intervention and potentially prevent the onset of disability. Increased physical activity, defined as any movement produced by skeletal muscles that require the spending of energy, is a known modifiable risk factor for the prevention of and management of chronic diseases.[30,31] Adults with chronic diseases benefit from physical activity.[31] In a recent meta-analysis (2013), increasing physical activity was shown to prevent and slow down functional decline in aging adults and in those with chronic diseases.[32]

The grip strength cutoff values developed from this study differed from some previously reported cutoff values.[4,17,18] The results from the current study's overall sample are very similar to results reported by Sallinen et al[18] in predicting LE disability with a grip strength cutoff for males at 37 kg and 21 kg for females. However, current study cutoffs were greater than reported from Laurenti et al,[4] who determined a cutoff of 30 kg for males and 20 kg for females in predicting LE disability, and Wang et al,[17] who determined a cutoff of 34 kg for males and 22 kg for females predicting UE disability. Differences in cutoff values among all of these studies could be accounted for by documented differences in grip strength and functional limitations that vary between adults in different countries.[19,21] The average BMI for both males and females in the HRS sample utilized in the current study was greater than those reported in the aforementioned studies. In overweight and obese males, grip strength cutoff values have been found to be greater as compared to normal weight males.[18] None of the previous studies explicitly investigated the role of multimorbidity in the development of grip strength cutoff values.

The AUCs generated from the analysis were considered low to moderate accuracy. The current study determined LE disability based on the self-report of difficulty walking several blocks. Other studies included difficulty walking or difficulty with steps to categorize adults with LE disability.[17,18] The addition of difficulty walking several flights of steps, asked to the HRS respondents, did not improve the AUC and were not included in the final results. Utilizing difficulty lifting 10 pounds to determine UE disability for this study was similar to Wang et al,[4] who utilized difficulty lifting 10 kg or difficulty with heavy housework. The self-report of physical disability by older

individuals has been validated and may reflect more accurately the true experiences of an individual; however, the onset of disability is multifactorial and other physical performance measures such as gait speed may provide additional information that improves a health care provider's ability to predict disability in a patient with multimorbidity.[15,18,28]

Strengths and limitations of the current study need to be addressed. A key strength was the use of a nationally representative data set of U.S. adults age 50 and older that includes both the presence of grip strength measurements, with the self-report of chronic diseases and disability. Self-reporting of chronic diseases has been found to have acceptable agreement as compared to objective confirmation of diagnosis.[41,42] Since the HRS is a longitudinal study, future research could focus on utilizing the grip strength cutoff values developed from this study and evaluate how effective the cutoffs were in predicting the onset of disability in adults with and without multimorbidity. One important limitation of this study was the AUCs determined from this study were on the border of being considered moderately accurate for both determining UE and LE disability.[25] Grip strength was used as an alternative measure for leg strength, which is essential for mobility, and grip strength has been reported as an indicator of overall muscle strength.[7,8] Numerous factors are believed to play a role in disability and no causality between low grip strength and disability is inferred in this cross-sectional research. Accounting for multimorbidity by a simple count of diseases avoids the issue that certain chronic diseases such as CVA have an increased association of disability as compared to other chronic diseases.[35]

By the year 2030, it is anticipated that the number of people with chronic conditions will reach 171 million.[2] It is the combination of chronic diseases and functional limitations that are related to increased health care costs.[3] Increasing physical activity is currently the best known intervention to prevent and manage chronic diseases and the development of disability.[32] The current system must move beyond its current single disease model, utilize tools that can predict disability, promote and assist patients in increasing levels of physical activity, and track outcomes of patients who participate in exercise programs and/or rehabilitation services. Interdisciplinary management of patients with multimorbidity provides the opportunity to provide patient-centered care and maximize functional abilities.

Conclusion

The current health care system is challenged with managing the growing number of adults with multimorbidity.[2] Determining an assessment that is cost-effective and easy to administer and has demonstrated reliability and the ability to predict disability is needed. Grip strength measurement can serve to predict both the onset of upper and lower extremity disability in adults with and without multimorbidity with similar accuracy. The implementation of grip strength into a physical assessment and the utilization of cutoffs would allow health care providers to monitor an older adult's performance and facilitate a referral to a rehabilitation professional prior to the onset of functional limitation.

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CHAPTER 5

THE UTILIZATION OF GRIP STRENGTH IN ADULTS WITH MULTIMORBIDITY AND PREVENTION OF DISABILITY

Introduction

The current United States (U.S.) health care system focuses on the treatment of single diseases, without consideration for multimorbidity and with little emphasis on prevention.[1,2] The growing number of adults with multimorbidity and functional limitations pose an increasing financial burden to the U.S. health care system.[3] Grip strength has been reported as an overall marker of health and body strength and is predictive of disability.[4-6] This dissertation investigated the relationship between grip strength, multimorbidity, and disability using data collected in the 2008 Health and Retirement Study (HRS). The HRS is a biennial, longitudinal survey that is representative of Americans age 50 and older.[7] Multimorbidity was found to have a negative predictive relationship with grip strength. Normative grip strength values were calculated stratifying the data by gender, age, and multimorbidity. Grip strength cutoff values were proposed in both males and females, with decreasing cutoff values in those adults with multimorbidity. The implementation of grip strength into routine physical assessments of adults with and without multimorbidity would allow both the patient and the provider to evaluate and monitor change over time and may promote the inclusion of exercise into a comprehensive intervention plan in order to prevent disability.

Grip Strength, Multimorbidity, Disability

The results of Chapter 2 of the dissertation demonstrated that multimorbidity has significant predictive relationship with grip strength in U.S. adults over the age of 50. As the number of chronic diseases increased, even when controlling for age and gender, grip strength decreased, in particular in those adults with three or more chronic diseases. The findings of this study promote the inclusion of number of chronic diseases, and not necessarily specific chronic diseases, into measuring grip strength in an adult with multimorbidity.

After determining the relationship of multimorbidity on grip strength, normative grip strength values based on age (decades), gender, and number of chronic diseases (0, 1, 2, ≥3) were calculated in Chapter 3. Grip strength norms are used in clinical practice to identify weakness and set rehabilitative goals.[8] Normative data should be representative of the population.[8] With the increasing number of adults with multimorbidity, including the number of chronic diseases in grip strength normative values provide health care providers, as well as patients themselves, a threshold of what is considered normal grip strength.

While the development of normative data is useful in clinical practice, identifying a grip strength cutoff value that could predict the onset of disability could encourage health care providers to intervene if a grip strength value would predict disability.[8] In Chapter 4, grip strength optimal cutoff values and cutoff values for 75% sensitivity based on gender and multimorbidity to predict self-report upper extremity and lower extremity disability were determined. Grip strength cutoff values decreased with increasing number

of chronic diseases, in particular in those adults with three or more chronic diseases. Grip strength cutoff values determined from this study provide a health care provider a threshold to consider referring an adult who falls below the cutoff value to a rehabilitation professional for an individualized program intended to maximize functional abilities.

Discussion

The number of Americans with multimorbidity is expected to reach 171 million people by 2030.[2] The current health care system, designed around a single disease model, is not providing high quality, cost-effective health care to adults with multimorbidity.[1,2] Changes in how patients with multimorbidity are managed and care delivered are inevitable.[2] The previous dissertation chapters provide evidence that decreased grip strength is associated with increasing numbers of chronic diseases, normative grip strength values developed for adults with multimorbidity are available to be implemented into practice, and cutoff values to predict UE and LE disability were generated that can help promote the prescription of exercise prior to the onset of disability.

The onset of disability is complex process. A recent (2013) study promoted the use of a multifactorial prediction model to predict disability in aging adults.[9] The number of chronic diseases, muscle strength (measured with grip strength), age, gender, and socioeconomic status were predictors of activities of daily living disability at a 10-year follow-up.[9] Utilizing a prediction model such as this could be used to screen adults at risk for development of disability and offer evidence-based prevention strategies and interventions. Increased physical activity is a known modifiable risk factor for the

prevention of and management of chronic diseases.[10] Physical activity is defined as any movement produced by skeletal muscles that requires the spending of energy.[11] Exercise is a subcategory of physical activity.[11] Adults with chronic diseases benefit from physical activity.[10] In a recent meta-analysis (2013), increasing physical activity was shown to prevent and slow down functional decline in aging adults and in those with chronic diseases.[12] Despite these known benefits, approximately only 16% of U.S. adults over the age of 55 meet both the aerobic and strengthening guidelines promoted in the *2008 Physical Activity Guidelines for Americans*.[10,13]

Primary care providers are positioned to provide guidance and counseling to their patients regarding physical activity.[14] Twenty-eight to 34% of U.S. adults report receiving exercise counseling at a medical visit; however, only 59% of primary care providers reported prescribing exercise for older adults.[15-17] A collaboration between the American College of Sports Medicine and the American Medical Association entitled Exercise Is Medicine® was initiated in 2007 to promote the known benefits of exercise to physicians and other health care providers.[18] The medical community has struggled to incorporate exercise prescription into practice due to working in a health care system designed for the treatment of disease and not prevention as well as inadequate training of physicians in exercise prescription.[19] An interdisciplinary approach for promoting the physical activity has been recommended.[14] Physical therapists are "health care professionals who maintain, restore, and improve movement, activity, and health enabling an individual to have optimal functioning and quality of life . . ." (p. 9).[20] The incorporation of grip strength into a physical examination and the utilization of grip

strength cutoffs would serve to predict the onset of disability and could then prompt a referral to a physical therapist trained in developing a comprehensive physical activity program designed to address functional abilities.

A key strength of this dissertation is the utilization of a nationally representative data set that promoted an interdisciplinary investigation on the relationship of grip strength, multimorbidity, and disability. The HRS is a longitudinal study completed every two years and includes self-report information on chronic diseases as well as physical measures collected utilizing standardized methods and trained testers. The sampling method of the HRS is intended to provide a representative view of the U.S. population. In comparison to other national studies, the HRS subsample used in this dissertation was similar in regard to gender, race, and reports of chronic diseases.

The work completed is also not without limitations. The state of disease management and specific medications for each of the respondents was unknown. Counting the number of chronic diseases does not take into account a chronic disease such as stroke, which has a high association with disability. In 2011, a group of researchers called for the standardization of grip strength measurement in epidemiological studies.[21] The data collected in 2008 deviated slightly from the proposed standards, including the use of a Smedley® dynamometer (as compared to the suggested JAMAR®), respondents stood (versus sitting), and two trials were completed (versus three). The Smedley's® dynamometer has been found to have a strong association with the JAMAR® ($r = 0.83$).[22] Standing during hand grip strength testing has been shown to produce higher strength values than when sitting.[23] The mean of two measurements of

grip strength has been found to have acceptable test-retest reliability ($ICC_{2,1} = 0.96$).[24] Despite the fact that the Jamar® hand dynamometer is accepted as the gold standard of measuring grip strength, the Smedley® has been utilized in several population-based studies including the Baltimore Longitudinal Study of Aging, Honolulu Heart Program/Honolulu Asia Aging Study.[21] The Jamar® requires at least three to four pounds of force in order to begin to measure, potentially rendering it inappropriate to use if a person is considerably weak.[21] According to an e-mail from HRS Questions (August 2013), the Smedley® was chosen for use in the HRS due to its ease of use and cost that was demonstrated in pilot work in two companion studies completed in Europe. One key limitation of this study was the AUCs determined from this study were on the border of being considered moderately accurate for both determining UE and LE disability.[25] The current study employed a cross-sectional analysis and does not imply causality of decreased grip strength due to the presence of chronic diseases nor between low grip strength and disability.

Since the HRS is completed every two years, future research could examine the longitudinal changes that occur with grip strength and the presence of chronic diseases over time, including the development of disability. Investigation of the role of race, grip strength, and multimorbidity could also be investigated. For both males and females, African-American have been reported to have stronger grip strength than those that are white.[26] Rates of multimorbidity also differ between racial and ethnic groups in the U.S.[27] and this should be examined in the future. Further investigation of other chronic diseases such as dementia, depression, and obesity or geriatric conditions such as urinary

incontinence and falling may also provide further clarification of the relationship between strength, multimorbidity, and disability.

Summary

Providing care for patients with multimorbidity has proven to be expensive, complex, and ineffective when care is provided within a single disease model.[1,2] In order to manage adults with multimorbidity, measures implemented by clinicians should be multifaceted and include physical performance measurements that are not markers of a single disease. Grip strength is a measurement of overall body strength.[4] Grip strength is impacted by multimorbidity and is able to predict upper and lower extremity disability. The medical community is recognizing the need to consider management beyond pharmaceuticals when managing adults with multimorbidity, including the prescription of exercise.[28] Increasing physical activity is known to prevent and manage chronic diseases.[12] Incorporation of grip strength as a physical measure that can be used to monitor physical status over time may allow early identification of declining strength and promote a referral to a rehabilitation professional (e.g., physical therapist) who can design an individualized exercise program intended to maximize physical and functional capacity.[28] Interdisciplinary management of patients with multimorbidity provides the opportunity to provide cost-effective, high quality patient-centered care dedicated to maximizing function and quality of life in adults with multimorbidity.

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Appendix

Human Subjects Institutional Review Board Approval Letter

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: October 19, 2011

To: Amy Curtis, Principal Investigator
Amy Yorke, Student Investigator

From: Victoria Janson, Interim Chair

Re: Approval not needed for HSIRB Protocol Number 11-10-26

This letter will serve as confirmation that your project "Fall Risk and the Older Cancer Survivor" has been reviewed by the Human Subjects Institutional Review Board (HSIRB). Based on that review, the HSIRB has determined that approval is not required for you to conduct this project because the study will analyze publicly available data. Thank you for your concerns about protecting the rights and welfare of human subjects.

A copy of your protocol and a copy of this letter will be maintained in the HSIRB files.

Walwood Hall, Kalamazoo, MI 49008-5456
PHONE: (269) 387-8293 FAX: (269) 387-8276