

HAND GRIP STRENGTH AS A NUTRITIONAL ASSESSMENT TOOL

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ABSTRACT

Hand grip strength (HGS) is a new nutritional assessment parameter proposed by American Society for Parenteral and Enteral Nutrition (ASPEN) and the Academy of Nutrition and Dietetics (the Academy) for diagnosis of adult malnutrition related to acute illnesses, chronic diseases or starvation. Identification of ≥ 2 of the following conditions is considered to be malnourishment – weight loss, loss of muscle mass, loss of subcutaneous fat, fluid accumulation, diminished HGS and inadequate energy intake. HGS is also a marker of sarcopenia, a condition defined by low muscle mass and low muscle strength or performance, as identified by the European Working Group on Sarcopenia in Older People. It has also been shown that lower HGS is associated with deficits in activities of daily living (ADL) and mobility. HGS is emerging as an important screening tool especially in the malnourished and aging population. This research evaluates the applicability of HGS as a nutrition screening tool in long-term care older adults.

Data from a total of 129 participants age ≥ 60 years involved in an ongoing walking program in long-term care facilities in Saskatoon available for analysis at the time this work was undertaken. Participants were randomly assigned for an intervention period of 16 weeks to one of three study groups: 1) Usual Care Group, 2) Interpersonal Interaction Group, and 3) Walking Program Group. Activity of daily living, cognition and depression scores and hand grip strength were recorded at baseline and every eight weeks. Information on vitamin D intake status prior to study commencement was also collected. This study provides values of low grip strength similar to those defined for the risk of sarcopenia in frail older adults. Stronger baseline HGS was correlated with greater ADL independence in females ($B=0.079$, $P=0.044$). Greater ability to eat at baseline was also associated with stronger grip in females when cognition status was taken into consideration. Baseline ADL ($B=-0.024$) and HGS ($B=1.004$) were significant predictors of

subsequent ADL and HGS, respectively, in males ($P < 0.01$). Baseline HGS was associated with subsequent ADL and HGS in females, but such association was modified by other covariates. In summary, if grip strength is to be used as a nutritional screening tool in long-term care facilities, dietitians shall be cautious of other factors such as the residents' cognitive status and age and use in conjunction with other nutrition assessment methods.

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ABBREVIATIONS

ADL	Activity of Daily Living
ASPEN	American Society for Parenteral and Enteral Nutrition
B	Unstandardized coefficient
BMI	Body Mass Index
CHS	Cardiovascular Health Study
CI	Confidence Interval
CSDD	Cornell Scale for Depression in Dementia
HGS	Hand Grip Strength
ICC	Intra-class Correlation Coefficient
IU	International Units
MMSE	Mini-Mental Status Examination
MNA	Mini Nutritional Assessment
MNA-SF	Mini Nutritional Assessment Short Form
OARS	Older American Resource Service
OR	Odds Ratio
RDA	Recommended Dietary Allowance
SE	Standard Error
SD	Standard Deviation
SGA	Subjective Global Assessment
SOF	Study of Osteoporotic Fractures
SPMSQ	Short Portable Mental Status Questionnaire
25(OH)D	25-Hydroxyvitamin D

CHAPTER 1 INTRODUCTION

1.1 Background

Falls in older adults result in detrimental outcomes that affect their activities of daily living (ADL) and quality of life. Falls may also lead to hospitalization, hip fractures (Dettoni, Peveraro, Dettoni, Rossi, Castoldi, Zareh et al., 2012), placement in long-term care homes, mortality and other comorbidities. Efforts have focused to prevent falls in older adults to avoid these serious health outcomes. However, prevention efforts have been difficult as multiple factors contribute to falls.

No one factor is solely responsible for a fall. Some of the common risk factors of falling include old age (Bischoff, Stahelin, Dick, Akos, Knecht, Salis et al., 2003; Samper-Ternent, Karmarkar, Graham, Reistetter & Ottenbacher, 2012), poor balance (Bischoff et al., 2003), frailty (Fried, Tangen, Walston, Newman, Hirsch, Gottdiener et al., 2001; Bilotta, Nicolini, Case, Pina, Rossi & Vergani, 2012) and polypharmacy (Chen, Peronto & Edwards, 2012). Among these factors, frailty is one of the risk factors that has recently gained increasing scientific attention.

There are different definitions of frailty in the literature. Usually frailty is characterized by the presence of weight loss, muscle weakness as measured by hand grip strength (HGS), exhaustion, slow walking speed and low physical activity levels (Fried et al., 2001). Within the definition of frailty is embedded the concept of sarcopenia – loss of muscle mass and muscle strength resulting in adverse health effects. This is a condition that is usually associated with increasing age (Cruz-Jentoft, Baeyens, Bauer, Boirie, Cederholm, Landi et al., 2010). Although controversies exist as to whether muscle mass or muscle strength is a better predictor of physical

impairment, functional assessment - such as hand grip strength - has gained popularity as a nutritional assessment tool in recent years (White, Guenter, Jensen, Malone, Schofield, Academy Malnutrition Work Group et al., 2012). Nutrition assessment and monitoring of nutrition-related physical findings form essential steps of the Nutrition Care Process. Accurate nutritional assessment permits better diagnosis of nutritional problems to provide better nutritional interventions.

In the literature, hand grip strength (HGS) has been shown to correlate with overall body strength (Lauretani, Russo, Bandinelli, Bartali, Cavazzini, Iorio et al., 2003; Norman, Stobaus, Smoliner, Zocher, Scheufele, Valentini et al., 2010). Hand grip strength has also been shown to correlate with various health outcomes, such as nutritional status, post-operation mortality and complications, cognition and ADL scores. The frailty algorithm includes weight loss as indicative of malnutrition and frail individuals were found to be more likely to be malnourished (Bollwein, Volkert, Diekmann, Kaiser, Uter, Vidal et al., 2013). Frailty has been consistently present in individuals with low muscle mass and strength and poor nutritional status (Dorner, Luger, Tschinderle, Stein, Haider, Kapan et al., 2014). Recent guidelines for dietitians and other health professionals have therefore recommended including HGS test as part of the screening procedure for malnutrition (White et al., 2012).

1.2 Purpose

The current literature consists of many studies on HGS and its associations with health outcomes. Cross-sectional studies show associations between HGS and various health indicators whereas longitudinal studies examine predictive impact of different HGS levels on future health outcomes. HGS tests are fairly non-invasive tests for patients and are quick to administer by health care professionals in clinical settings using standardized procedures. Current nutrition-

related physical assessment methods, such as the Subjective Global Assessment (SGA), and functional assessment, such as ADL questionnaires, for example, require subjective judgements from experienced health care professionals. The results of these methods often fluctuate widely depending on the skill and training of the individuals who perform the assessments (Detsky, McLaughlin, Baker, Johnston, Whittaker, Mendelson et al., 1987; McGinnis, Seward, DeJong & Osberg, 1986). These screening methods for malnutrition and physical functions also take longer to perform than HGS. As a result, HGS may allow for more objective and faster identification of patients at risk, allowing for early commencement of nutritional interventions to attenuate worsening of health conditions.

Unfortunately, the majority of the studies on the associations of HGS and health outcomes have been done in community-dwelling healthy adults or hospital in-patients undergoing surgery. Evidence of the determinants of HGS as well as the health outcomes that it predicts are also more abundant in healthy adult populations and only a limited number of studies have been done in institutionalized older adults. Older adults living in long-term care have many unique characteristics which differentiate them from community-dwelling healthy older adults. Therefore, the values and interpretation of HGS in community-dwelling older adults may not be generalizable to those in long-term care.

The purpose of the current study was two-fold. First, it examined whether HGS could be used as a quick and simple screening tool in place of ADL questionnaires to identify long-term care residents who may be at risk of frailty and accelerated onset of physical impairment. To achieve this, the correlation of baseline HGS with ADL in long-term care older adults was tested at cross-sectional and longitudinal time points to examine whether HGS could predict current and future ADL independence. Secondly, this study also examined factors which may potentially

affect the performance of HGS in an institutionalized setting. This research may help future health care practitioners account for confounding factors that influence HGS performance in a clinical setting.

1.3 Objectives

The objectives of the current study are as follows:

1. To determine whether an association of ADL and HGS exists at cross-sectional and longitudinal time points.
2. To assess whether the association between ADL and HGS is influenced by confounders.
3. To determine factors that influence HGS in an institutionalized setting at cross-sectional and longitudinal time points.

1.4 Hypothesis

The hypothesis of the current study is as follows:

Hand grip strength is a significant predictor of activity of daily living score in older men and women residing in long-term care.

CHAPTER 2 LITERATURE REVIEW

2.1 Falls in Older Adults

Increased age is associated with a wide array of physiological changes. Accidental falls among the elderly (age ≥ 65 years) are detrimental to the patients and their family and deserve preventative attention. Falls occur in older adults in both long-term care (Neyens, Haastregt, Dijcks, Martens, Heuvel, Witte et al., 2011) and communities (Fried et al., 2001) settings. In 2008, the age-standardized mortality rate per year due to falls among older adults age 65 years and above was 4.7 per 10,000. In the same year, males had a mortality rate of 5.7 and females had a rate of 4.1 due to falls (per 10,000) (Public Health Agency of Canada, 2014). Some serious consequences of falls in older adults include fractures, requirement for walking aids, hospitalization and placement in long-term care facilities (Dettoni et al., 2012). Falls are the direct causes of most hip fractures and 20% of those cases lead to death (Public Health Agency of Canada, 2014). The mortality rate of older patients with hip fractures is significantly higher than healthy individuals (Dettoni et al., 2012).

The causes of falls are complex, multi-factorial and often interdependent. Significant risk factors for individual and repeated falls include increased age, female sex, depression, poor balance, decreased cognition, disability, medical comorbidity, previous history of falling, frailty and polypharmacy (Bischoff et al., 2003; Boyle, Naganathan & Cumming, 2010; Chen et al., 2012; Fried et al., 2001; Moniz-Pereira, Carnide, Ramalho, Andre, Machado, Santos-Rocha et al., 2013; Samper-Ternent et al., 2012). Polypharmacy is a particularly significant predictor of fall incidence in older adults (Chen et al., 2012) because individuals taking a higher number of medications exhibit higher odds of subsequent falls (Moniz-Pereira et al., 2013). Polypharmacy does not only have a detrimental impact by itself, but it is also associated with higher number of

chronic conditions, especially in women (Moniz-Pereira et al., 2013), which themselves increase fall risk.

The mechanism in which medications may affect falls has been found to be a detrimental impact on balance, especially in recurrent fallers (Bischoff et al., 2003; Boyle et al., 2010; Chen et al., 2012; Moniz-Pereira et al. 2013). For example, antidepressants have been shown to affect balance and result in higher risk of falls (Boyle et al., 2010). From a cross-sectional assessment of balance tests between non-fallers and episodic (having fallen once in the previous year) and recurrent (having fallen at least twice in the previous year) fallers, subsequent fallers had worse balance than non-fallers (Moniz-Pereira et al., 2013). The same authors further highlighted that falls that had occurred at least twice in the previous year for an individual were also more likely due to intrinsic factors such as fear of falling and personal health perception (Moniz-Pereira et al., 2013). In addition to these factors, frailty (Fried et al., 2001; Bilotta et al, 2012) is also a significant predictor of falls. In conclusion, many different factors contribute to falls and they are often interdependent upon one another, resulting in challenges in assessing, preventing and intervening with patients at risk.

2.2 Frailty in Older Adults

2.2.1 Characteristics of Frailty

Falls are frequent outcomes in frail individuals. Frailty is one of the cumulative results of physiological changes of aging and its prevalence is high even in community-dwelling older adults. A frail phenotype has been proposed by many groups and is commonly defined as having characteristics of three or more of the criteria: unintentional weight loss or muscle loss, weakness with low grip strength, self-report of exhaustion, slow walking speed and low level of physical

activity from the Cardiovascular Health Study (CHS). Pre-frail individuals are characterized by one or two of the defined criteria (Fried et al., 2001). Individuals who were diagnosed as frail at baseline had a high incidence of first fall in the 3- and 7- years follow up periods. In addition, these individuals required more frequent hospitalization, had higher activity of daily living (ADL) dependence and had lower mobility. Individuals in the pre-frail group at baseline in this study had a higher chance of first fall incidents ($P < 0.05$) than the frail group ($P = 0.06$) over 7 years, after adjustments for covariates (Fried et al., 2001). This finding is supported by another prospective study in which the incidence of falls over 2-years was higher in individuals that were pre-frail, but not frail (Samper-Ternent et al., 2012). The authors suggested that subjects from the pre-frail group had higher mobility and independence than individuals belonging to the frail group, resulting in their higher risk of fall. A higher level of support from caregivers may also make the risk of falls in the frail group drop to an undetectable level (Samper-Ternent et al., 2012). This suggests that interventions can be instituted to make frail individuals less likely to fall.

A study in Asia with community dwelling subjects aged 65 years and above defined frailty as being underweight, having low hand grip strength, having impaired muscle performance and low muscle mass (Auyeung, Lee, Kwok & Woo, 2011). Subjects, who were all cognitively normal at the beginning of the study according to the Mini-Mental State Examination (MMSE), had their cognitive function assessed at baseline and at 4-year follow up. The MMSE is a 30 point scale designed and validated to measure cognitive function in patients with Alzheimer's Disease (Folstein, Folstein & McHugh, 1975). It consists of 11 questions and tasks administered by an interviewer to assess a patient's orientation, memory, attention, naming, ability to follow verbal commands, writing a sentence and copying of intersecting-pentagons.

Participants with weaker hand grip strength and worse neuromuscular performance at baseline have been found to be at greater risk of dementia after 4 years with adjustment for age and baseline cognitive score (Auyeung et al., 2011). Thus, the authors suggested that frailty and falls often co-exist with dementia.

Frailty has also been defined based on the Study of Osteoporotic Fractures (SOF) criteria (Bilotta et al., 2012). The SOF criteria are simpler than the ones proposed by Fried et al., but the major considerations of factors and predictions are essentially similar. Diagnosis of frailty is based on identification of at least two of the three components: weight loss of more than 5% in the previous year, inability to rise from a chair without using the arms for five consecutive times and self-report of low energy level (Bilotta et al., 2012). In general, those that are frail are usually older women with less mobility, higher comorbidity and higher depression score (Bilotta et al., 2012; Fried et al., 2001). Such characteristics are similar to those of fallers, which may explain the high ability of frailty to predict falls. Although frailty significantly predicts incidence of falls, hospitalization and mortality and encompasses different aspects of physiological changes, further diagnostic definitions are beneficial to research and clinical assessments. The different algorithms of frailty are summarized in Table 2.1.

There is overlap between malnutrition and frailty. The diagnosis of undernutrition in adults has recently been characterized by two or more of the six criteria according to the Academy of Nutrition and Dietetic (The Academy) and American Society for Parenteral and Enteral Nutrition (ASPEN): insufficient energy intake, weight loss, loss of muscle mass, loss of subcutaneous fat, fluid accumulation and diminished hand grip strength. The differentiation between starvation-, acute illness- and chronic disease-related malnutrition depends on the extent of severity of these criteria (White et al., 2012).

The current literature does not have many studies which assess the association of frailty and malnutrition as defined by The Academy and ASPEN. However, the shared characteristics of malnutrition and frailty may suggest that both can be measured using similar assessment tools for screening. Despite the lack of studies on comparing the two definitions, many studies are available at examining nutritional status using the Mini Nutritional Assessment (MNA) and frailty in the literature.

The MNA is a validated nutritional assessment test for the elderly that covers anthropometric measures, global assessments (consist of lifestyle, medication and mobility), dietary questionnaires and subjective assessments (including self-perception of health and nutrition). It assesses malnutrition items such as weight loss, body mass index (BMI), arm and calf circumferences, stress or acute diseases, neuropsychological problems, skin ulcers, anorexia, number of meals, beverage intakes, protein rich foods, fruits, living independence and difficulties with feeding (Bollwein et al., 2013; Guigoz, Vellas & Garry, 1996; Vellas, Guigoz, Garry, Nourhashemi, Bennahum, Lauque et al., 1999). A cross-sectional study in community-dwelling older adults aged 75 years and above showed that individuals who were pre-frail and frail had higher prevalence of being at risk of malnutrition as assessed by the MNA compared to non-frail individuals (Bollwein et al., 2013). In the same study, over 90% of individuals at risk of malnutrition were either pre-frail or frail. Similar results were found in a sample of acute care hospital inpatients (Dorner, et al., 2014). About 80% of the patients who were at risk of malnutrition, using the short form of the MNA (MNA-SF), were pre-frail or frail (Dorner, et al., 2014). Although the prevalence of risk of malnutrition was higher in community-dwelling sample, no individuals were found to be malnourished whereas 25% of the acute hospital patients were malnourished (Dorner et al., 2014). Upon examination of individual MNA items

across frailty criteria, those that were frail had significantly higher prevalence of food decline, impaired mobility and calf circumference <31cm (Bollwein et al., 2013; Dorner et al., 2014). Dorner and colleagues (2014) have also used reliability analysis to compare internal consistency between MNA-SF items and frailty criteria. Results showed that the dietary (loss of appetite, food decline and weight loss), functional (impaired mobility, fatigue, difficulties walking and climbing stairs and low physical activity) and muscular (calf circumference and hand grip strength) components were strongly consistent between the MNA-SF and frailty scales (Dorner et al., 2014). The MNA could partially identify frailty (Bollwein et al., 2013), but it would be more accurate if used in conjunction with frailty assessment to indicate the needs of early intervention (Dorner et al., 2014). As a result, the common criteria in defining malnutrition and frailty can be used to help diagnose both conditions and design timely interventions.

Table 2.1 Frailty Definition Criteria

Criteria	Cardiovascular Health Study ¹	Auyeung et al. (2011)	Study of Osteoporotic Fractures ²
Weight loss	√		√
Underweight		√	
Weak grip strength	√	√	
Chair rise		√	√
Slow walking speed	√	√	
Self-reported exhaustion	√		√
Low physical activity	√		
Muscle mass		√	

¹Fried et al., 2001: Frailty defined by identification of at least 3 criteria. Pre-frail defined by identification of 1-2 criteria

²Bilotte et al., 2012

2.2.2 Comparison of Frailty Scales

Several frailty scales are used in clinical settings and the literature. As explained earlier, the SOF scale and the one defined by Fried et al., (2001) in the CHS are some of the commonly used scales. A longitudinal cohort study has compared the ability of the SOF and the CHS scales along with two other frailty scales – the Frailty Index and the FRAIL scale - to predict additional ADL disability in the future (Malmstrom, Miller & Morley, 2014). The Frailty Index considers clinical symptoms, signs, diseases, laboratory measurements and disabilities as deficits. Each deficit is assigned a score of 1 if it is present and the score is summed over the total number of assessment items. It is based on the concept that an individual who has more health problems is more likely to be frail (Rockwood & Mitnitski, 2007). The FRAIL scale is an interview based questionnaire administered by health care professionals regarding frequencies of fatigue, difficulties in using stairs and walking, illness and weight loss (Abellan van Kan, Rolland, Bergman, Morley, Kritchevsky & Vellas, 2008). In general, the Frailty Index was found to be better at predicting ADL disability than all other scales at 3-year follow up and equivalent to the FRAIL and CHS scales at 9-year follow up (Malmstrom et al., 2014). The authors suggested that inclusion of more comorbidity items in the Frailty Index may provide greater predictive power of ADL. However, the practicality of the Frailty Index in clinical settings may be limited since it requires a fairly large number of deficits to yield a risk of adverse outcomes regardless of the specificity of the health variables that are chosen (Rockwood & Mitnitski, 2007). There is no doubt that most frailty scales can identify frail individuals at risk of developing adverse health outcomes but the scales are specific to the characteristics of the group of individuals, thus resulting in different prevalence of frailty (Theou, Brothers, Mitnitski & Rockwood, 2013).

In comparison of eight frailty scales from the Survey of Health, Ageing, and Retirement in Europe, the prevalence of frailty identified ranged from 6.1-43.9% in non-institutionalized population aged 50 years and above (Theou et al., 2013). The authors also found that scales based on interview and self-reported responses were more practical to apply in a clinical setting and more missing values were found in scales that employed performance-based tests, such as hand grip strength, due to incompleteness related to impairment. However, it was found that individuals who had missing values for physical performance test were more likely to have poorer health and had three times higher mortality rate. As a result, the individuals who were unable to perform these tests were frailer than those who could complete them resulting in selection bias of the tests (Theou et al., 2013). In addition, one would also expect that self-report measure would be less accurate in populations with high rates of dementia, such as nursing homes. Overall, the ability of each frailty scale to predict adverse health outcomes should also be considered with caution. Mortality is often conveniently used as an outcome of frailty in longitudinal study, but the ability of predicting mortality rate differs depending on the choice of frailty scale (Theou et al., 2013). In conclusion, the choice of frailty scale should be appropriate for the population in question as well as its feasibility in clinical settings for identification of frail individuals. The challenge of developing a standardized frailty scale for assessment remains.

2.3 Sarcopenia in Older Adults

2.3.1 Characteristics of Sarcopenia

According to the European Working Group on Sarcopenia in Older People, sarcopenia is defined as a loss of muscle mass and muscle strength or performance resulting in adverse health outcomes and poor quality of life (Cruz-Jentoft et al., 2010). Using this definition, sarcopenia is related to criteria of frailty as defined previously and is a contributor to frailty in older adults.

It is intuitive to associate the losses of muscle mass and strength with higher risks of frailty, falls, immobilization and ADL dependence, although other variables also have contributing parts to the frail phenotype. The term “sarcopenia” only described muscle mass loss related to aging when it was first introduced (Manini & Clark, 2012). However, as research on the relationship between older adults’ loss of muscle mass and physical function decline progressed, reduction of muscle mass has been deemed to be an inadequate sole predictor, and loss of muscle strength has been incorporated into the definition of sarcopenia (Cruz-Jentoft et al., 2010; Abella van Kan, Houles & Vellas, 2012; Lauretani et al., 2003; Manini & Clark, 2012). When appendicular lean mass and skeletal muscle index, adjusted for stature, were used to measure lean body mass and define prevalence of sarcopenia in community dwelling older adults (age 78-95), both indices showed varying results (Merriwether, Host & Sinacore, 2012). Appendicular lean mass predicted a prevalence of 49% whereas skeletal muscle index predicted 84% of sarcopenia. Furthermore, only a small significant difference existed in lower extremity strength in women between the sarcopenic and non-sarcopenic groups categorized by appendicular lean mass (Merriwether et al., 2012). As a result, sarcopenia is a condition that needs to account for both losses of muscle mass and strength.

Comparison of strength performance tests and muscle area showed varying results for physical functions. Calf muscle area was the poorest predictor of physical function decline, which was defined as walking speed slower than 0.8m/s and inability to walk 1km without difficulties. However, muscle strength parameters, such as hand grip strength, knee extension torque and lower extremity muscle power, better predicted physical function impairment (Lauretani et al., 2003). Growing evidence has suggested the separation of muscle strength loss from the definition of “sarcopenia” and the development of its own term of “dynapenia” to solely

account for reduction of physical functions in older adults (Abella van Kan et al., 2012; Manini & Clark, 2012). A systematic review carried out by Manini and Clark (2012) has looked at the association of muscle mass and muscle strength with poor physical performance among older adults in the literature. They found that using muscle strength as a predictor of physical impairment was significant 90% of the time whereas muscle mass as a predictor was only significant 35% of the time. It is tempting to include the use of muscle strength parameters only for physical assessments; but muscle area measurements have still been found to be significant predictors in the Lauretani et al (2003) study. Therefore, it is likely premature to fully exclude the loss of muscle mass in the prediction of frailty.

2.3.2 Links between Sarcopenia, Frailty and Falls

As mentioned earlier, sarcopenia is embedded into the definition of frailty in older adults. The pathogenesis of frailty directly and indirectly links risk factors leading to sarcopenia with health outcomes such as disability and falls, as shown in Figure 2.1 (Chen, Mao & Leng, 2014). Several factors contribute to sarcopenia and frailty. Chronic diseases with elevated levels of pro-inflammatory cytokines and immune cells have shown to be associated with frail individuals. Decreasing levels of testosterone in men, estrogen in women, growth hormone and insulin-like growth factor 1 with increasing age also contribute to losses of muscle mass and strength in older men and women (Chen et al., 2014; Cooper, Dere, Evans, Kanis, Rizzoli, Sayer et al., 2012) as observed in frail individuals.

In addition, both hormonal changes and cytokines affect muscle synthesis and breakdown, imbalance of bone resorption and formation leading to osteoporosis (Cooper et al., 2012) and muscle structures (Chen et al., 2014). A cross-sectional study on healthy postmenopausal women age 50 years and above in Korea showed reduced bone mineral density

at the spine, femur neck and total hip to be associated with lower grip strength (Kim, Lee & Cho, 2012). The study helps to illustrate the pathogenesis of frailty leading to an adverse health outcome through the endocrine and musculoskeletal systems mechanism. Along with increasing age as a risk factor, postmenopausal changes in hormone levels leads to lower bone mineral density resulting in increased risk of osteoporosis. This affects the musculoskeletal system in which reduced hand grip strength and lower bone mineral density are observed, leading to higher risk of bone fractures (Kim et al., 2012). The effects of cellular and molecular changes on sarcopenia and frailty were not investigated in this study. However, it has been shown that inflammatory cytokines also contribute to skeletal muscle protein breakdown and changes in muscle mass influences bone metabolism (Cooper et al., 2012). Cellular changes related to aging lead to impaired physical functions as observed in frailty individuals, which further increase the risk of detrimental health outcomes such as falls and ADL dependency.

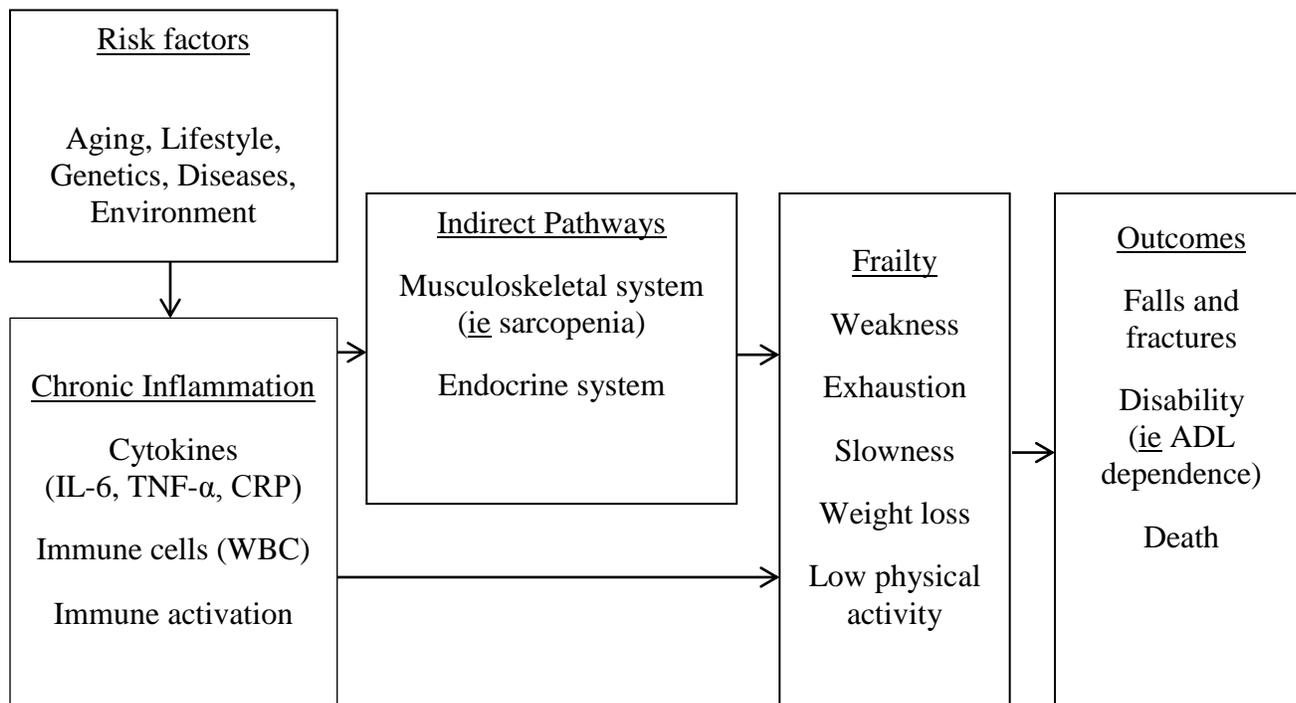


Figure 2.1 Mechanism of Sarcopenia, Frailty and Health Outcomes.

Abbreviation: IL-6: Interleukin 6; TNF- α : Tumor necrosis factor α ; CRP: C-reactive protein; WBC: White blood cells; ADL: Activity of daily living (diagram modified from Chen et al., 2014).

2.3.3 Measurement Tools for Sarcopenia

In addition to the controversies on the definitions of sarcopenia, the methods of measuring muscle mass and muscle strength are also problematic issues. Different techniques have been used to measure these, including dual energy X-ray absorptiometry, bioimpedance analysis, skin fold thickness and muscle cross-sectional area for muscle mass. Handgrip strength, knee-extension torque and lower extremity power are commonly used to assess muscle strength (Cruz-Jentoft et al., 2010; Lauretani et al., 2003; Merriwether et al., 2012). Although different methods have been used in the literature, the gold standard for diagnosis of sarcopenia is yet to be identified. However, recent guidelines promote the use of hand grip strength by dietitians and other health professionals as a mean of functional assessment for nutritional status (White et al., 2012) and it is gaining popularity in the literature. The common criteria for frailty, sarcopenia and malnutrition are summarized in Table 2.2.

Table 2.2 Criteria for Frailty, Sarcopenia and Malnutrition

Frailty ¹	Sarcopenia ²	Malnutrition ³
Unintentional weight loss	Low muscle mass	Inadequate energy intake
Low hand grip strength	Low hand grip strength	Weight loss
Slow walking speed	Poor physical performance	Loss of muscle mass
Low physical activity		Loss of subcutaneous fat
Self-reported exhaustion		Fluid accumulation
		Low hand grip strength

¹Fried et al., 2001. Frailty defined by identification of at least 3 out of 5 criteria.

²Cruz-Jentoft et al., 2010. Sarcopenia defined by presence of low muscle mass plus either low hand grip strength or poor physical performance.

³White et al., 2012. Malnutrition defined by identification of at least 2 out of 6 criteria.

2.4 Characteristics of Adults Living in Long-Term Care Facilities

2.4.1 Reasons for Long-Term Care Admission

A variety of health facilities and services are available to older adults. Assisted living arrangements are usually more accessible to more independent individuals with better financial resources. They generally provide non-medical assistance and social support to seniors with chronic illnesses and disabilities. The aim of assisted living is to provide these services while allowing service receivers to maintain functional independence and self-reliance simultaneously (Service Canada People Serving People, 2014). Long-term care facilities (or nursing homes), on the other hand, provide full medical and nursing care as well as accommodations, personal support and nutrition for seniors who require higher level of care. Individuals generally move to long-term care homes when they require more complex care needs and supervision that cannot be met by assisted living services (British Columbia Health & Safety, 2014). In Canada, both assisted living facilities and long-term care homes follow rules set at the provincial and territorial levels and public funding eligibility varies across different jurisdictions (Health Canada, 2004).

The factors for transfer of seniors from the community to long-term care encompass both social and physiological aspects. Individuals in long-term care settings usually have more functional and cognitive impairments than those in the community. In the Prairie Provinces of Manitoba, Saskatchewan and Alberta, at least 60% of long-term care residents are diagnosed with Alzheimer's disease or another dementia. Twenty percent of the residents have also experienced a stroke in the past which limited their functional ability (Estabrooks, Poss, Squires, Teare, Morgan, Stewart et al., 2013). Residents were more likely to suffer multiple comorbidities and were prescribed multiple medications (Estabrooks et al., 2013; Heckman, Foebel, Dubin, Ng, Turpie, Hussack et al., 2013). In Nova Scotia, worsening of dementia and/or medical illnesses

and caregiver factors were common reasons for admission to long-term care facilities (Rockwood, Richard, Garden, Hominick, Mitnitski & Rockwood, 2014). In this study, all individuals who transferred from assisted living to long-term care facilities were diagnosed with dementia and 91% who transferred from the community to long-term care homes were demented. The authors found that individuals who were more dependent, less mobile and had poorer balance were more likely to consider long-term care homes or assisted living options. Impaired ADL, especially the inability to prepare meals, has been found to result in individuals moving out of the community (Rockwood et al., 2014). Hospitalization is also a precipitant for a move – about 50% of the residents were admitted from hospital (Heckman et al., 2013). However, the effect of hospitalization was not as strong as worsening of the underlying health conditions (Rockwood et al., 2014). Reasons for moving into health care facilities after hospitalization include unsettled health problems or the concerns by the health care team about discharging senior patients home alone. Caregiver health, stress and incapability to provide care were also found to be factors triggering a move into health care facilities (Rockwood et al., 2014).

Long-term care homes consist of a wide spectrum of age groups and reasons for admission into long-term care may vary within these. A study in a Calgary long-term care home compared the quality of life of residents between age ≤ 65 years with those > 65 years (Watt & Konnert, 2007). In this study, 51.2% of the younger residents were males. In general, younger residents had better perceived health than older residents and 55.8% of them rated their health as excellent or good. However, younger residents had more functional disabilities due to multiple sclerosis and traumatic brain injury or stroke. In contrast, older residents were mostly female and a lower percentage of them (39.5%) perceived their own health to be excellent or good. In terms

of functional independence assessed by ADL, younger residents were more dependent in overall ADL compared to older ones. Younger residents often retained strength, but mobility was limited due to injury. No difference was found between the two age groups in terms of their quality of life. Further analyses of the younger residents' quality of life revealed that they were content with their psychological and spiritual wellbeing in spite of physical limitations. In fact, quality of life may be correlated more with perceived health status than with functional status in this subpopulation (Watt & Konnert, 2007). However, exclusion of residents with cognitive disability in this study meant that the authors could not examine the difference in cognitive status between the younger and older groups. The generalizability of this study may also be limited as it was based on one facility only. However, in spite of its limitations, this study was useful in illustrating that differences between long-term care residents may result in different outcomes and therefore different care and service needs.

2.4.2 Psychological Health

Long-term care homes often aim to provide care with the provision of sustaining residents' quality of life. However, quality of life of long-term care residents may be greatly compromised due to depression and anxiety in such setting (Beerens, Zwakhalen, Verbeek, Ruwaard & Hamers, 2013). Poor quality of life may be related to health-related distress (Hall, Davies, Gao & Higginson, 2014) and self-perception of disease prognosis (Liu, Weng & Wu, 2014) by the individual. The concept of dignity encompasses important human perspectives, including role preservation, maintenance of pride, autonomy and acceptance, and has been found to be important to quality of life. A measurement system, the Patient Dignity Inventory, was developed by Chochinov et al. (2008), to assess patient dignity in palliative care setting. Using this scale, it was shown that residents with higher number of dignity issues, such as

psychological, spiritual and existential distresses, were found to have poorer quality of life and increased rate of depression (Hall et al., 2014). In this study with long-term care residents in the United Kingdom, the most prevalent issues identified were experiencing physical distress symptoms, not being able to continue usual routines and inability to carry out tasks of daily living using the Patient Dignity Inventory. This study also found that the inability to carry out usual routine and tasks of daily living and unable to fight mental challenges associated with illness were significantly associated with increased depression and poorer quality of life. In addition, individuals with more dignity concerns were found to have worse ADL functionality and performance status. Another study on residents recently admitted to long-term care facilities in Taiwan illustrated the importance of residents' perception of their own health (Liu et al., 2014). Residents with knowledge of their health had better prediction of their health trajectories (Liu et al., 2014) and might be less influenced by anxiety caused by uncertain disease prognosis. The relationship between depression and reduced functionality and performance may form a vicious cycle – functionality and performance independence decrease with the presence of illness and individuals become depressed with their deteriorating health; as these individuals become more depressed, they develop more problems related to anxiety and self-perception of functionality which further worsen their depressive status.

Depression has also been found to be more prevalent in long-term care settings than in the community and the reported prevalence of major depression in such setting ranges from 5% to 25% (Seitz, Purandare & Conn, 2010). However, the reported prevalence of depression is often different across long-term care settings because of variations in diagnostic methodology (McCusker, Cole, Voyer, Monette, Champoux, Ciampi et al., 2014; Seitz et al., 2010) as well as confounding signs and symptoms. The signs and symptoms of depression overlap with those of

anxiety and even other medical illnesses (McCusker et al., 2014). A descriptive cross-sectional study in Quebec examined the prevalence of psychological distress and key variables associated with it (Voyer, Verreault, Cappeliez, Holmes & Mengue, 2014). Psychological distress was defined as frequently or always exhibiting at least one of the following symptoms in the past week: looking sad and depressed, reporting sadness and depression, sounding sad and depressed, looking worried and anxious, reporting worries and anxiety and crying. Among 1999 residents, 45.6% of them were considered psychologically distressed. Within this sample, 21% of them showed frequent comorbidity of depression and anxiety. The authors also found that more severe cognitive impairment was significantly associated with greater psychological distress (Voyer et al., 2014) and depression (Gruber-Baldini, Zimmerman, Boustani, Watson, Williams & Reed, 2005). In this long-term care population, it was difficult to separate depression and dementia as the symptoms of depression could present as secondary to cognitive impairment and vice versa (Voyer et al., 2014). On the other hand, extrinsic factors, such as living condition and the lack of self-autonomy in long-term care, could also impact the quality of life and psychological well-being of residents (Hall et al., 2014; Voyer et al., 2014), thus further confounding the identification of depression.

A study with long-term care residents by McCusker et al., (2014) could be used as an example to illustrate the effect of multiple risk factors and diseases contributing to depression. In this study, significant risk factors for depression in long-term care residents have been found to include delirium, pain and diabetes. Over the study period of 6 months, McCusker and colleagues (2014) found that the incidence of depression was 73.3 per 100 person-years. They also observed that changes in cognitive status, delirium, uncorrected visual impairment and hearing impairment were significantly associated with increased depression in this setting.

Among these factors, changes in cognitive status frequently preceded the development of depression whereas other factors seemed to concurrently change with worsening of depression over time. However, the authors noted that causality could not be inferred from this study because of its design. The authors further suggested that the pathophysiology of depression may be confounded with delirium and other health conditions and thus screening results were often misinterpreted. As a result, despite physical suffering, psychological distresses should also be considered while providing care because they could influence the quality of life of residents residing in long-term care homes.

2.4.3 Behavioral Symptoms related to Cognition

Cognitive impairment, including dementia, is associated with long-term care admission (Wang, Shamliyan, Talley, Ramakrishnan & Kane, 2013) and is very common among long-term-care residents (Estabrooks et al., 2013). In a cross-sectional survey in long-term care residents, 60% of the participants were diagnosed with dementia upon admission (Brazil, Maitland, Walker & Curtis, 2013) and agitation and aggression related to cognitive impairment were associated with more rapid independence decline (Messinger-Rapport, Gammack, Thomas & Morley, 2013). These residents are more likely to exhibit difficult behaviors, especially during the care process (Messinger-Rapport et al., 2013), for reasons that are not fully understood but are thought to be related to lower level of tolerance, invasion of personal space during the care process, or increased stress and anxiety related to relocation to long-term care facilities (Brazil et al., 2013). Behavior symptoms of dementia may include physical aggression, agitation, wandering, culturally inappropriate behaviors, cursing, hoarding, shadowing, screaming, restlessness and sexual disinhibition. The more common behaviors that residents with dementia exhibited at admission were pacing, aimlessly wandering, trying to get to different places and

general restlessness and aimlessly wandering was the most disruptive behavior three months post-admission into long-term care facilities (Brazil et al., 2013). Psychological symptoms include anxiety, depression, hallucinations and delusions (Brazil et al., 2013; Fischer, Cohen, Forrest, Schweizer & Wasylenki, 2011). Other disruptive behaviors by residents with dementia that interrupted care include verbally agitated behaviors such as complaining and constant requesting for attention (Brazil et al., 2013).

These behavioral symptoms of dementia may increase the risk of falls, but they also often increase the use of psychotropic medications as well, which may also increase falls. For example, among residents that were referred for psychotropic medication consultation, 60.3% of them were referred due to behavioral and psychological symptoms of dementia and 71.2% of them were diagnosed with cognitive disorder (Fischer et al., 2011). The authors found that the most commonly prescribed medications were antipsychotics, antidepressants and cognitive enhancers. In addition, the use of antipsychotics was associated with symptoms of dementia whereas the use of cognitive enhancers was associated with the diagnosis of cognitive disorder (Fischer et al., 2011). The authors further commented that the use of antidepressants might be used to treat dementia symptoms which could overlap symptoms of depression. The widespread use of these psychotropic medications reflects the common emergence of cognitive disorders in residents of long-term care setting.

2.4.4 Nutritional Status

Malnutrition is prevalent in long-term care home settings and it is shown to be associated with multiple medical conditions common in such settings (Kaiser, Bandinelli & Lunenfeld, 2010; Messinger-Rapport et al., 2013). In Canada, severity of dementia, unstable health conditions and depression were significantly associated with malnutrition (Bostrom, Soest,

Kolewaski, Milke & Estabrooks, 2010). In the same study, among 55 veterans living in residential centres, MNA identified only 11% of the residents as well nourished; the rest were identified as - 58% with risk of malnutrition and 31% as malnourished. Malnourished individuals had smaller mid-arm and calf circumferences, poorer self-perception of malnutrition, greater weight loss and global disabilities (including mobility, neuropsychological problems, polypharmacy, independence and presence of pressure sores). Within the dietary component of the MNA, only 35% of the residents managed to feed themselves independently whereas 65% of them were unable to feed without assistance or had trouble feeding themselves (Bostrom et al., 2010). The inability to eat independently may further exacerbate existing malnutrition. Using validated screening tools for nutritional status, such as the MNA, long-term care residents at risk of malnutrition could be identified; however, since malnutrition could be associated with several risk factors, diagnoses and treatments of underlying causes could be difficult and challenging. The identification of nutrition risk was also related to diagnoses of comorbid conditions such as dementia, depression and health instability. The emotions and psychological well-being of residents have also shown to greatly affect their food intake (Salva, Coll-Planas, Bruce, De Groot, Andrieu, Abellan et al., 2009). As a result, if the prevalence of these health conditions were underestimated and not addressed at admission, they could precipitate to worsen nutritional status of residents in long-term care.

Other approaches were also used to assess and screen nutritional status in long-term care homes and differences in methods may contribute to variation in prevalence of malnutrition. A study in Ontario examined anthropometric measures, including BMI, triceps skin fold and mid-arm circumference, and fat free mass to reflect nutritional status to determine whether they were associated with mortality risk in residents of long-term care (Allard, Aghdassi, McArthur,

McGeer, Simor, Abdolell et al., 2004). At a longitudinal time frame, greater BMI, skin fold and arm circumference, which reflected better nutritional status, were associated with lower risk of mortality. However, since these body compositions change with age, other nutrition assessments may be more appropriate in older adults. As a result, the use of these inappropriate parameters might have contributed to the apparent wide spectrum of nutritional status in this population (Allard et al., 2004). However, it has been shown that BMI below the 15th percentile in seriously ill hospital patients was associated with increased mortality in 6 months and a BMI less than 19 kg/m² for men and below 19.4 kg/m² for women were defined as undernutrition. In the USA, the current national sets of standards for nutrition assessment in long-term care facilities suggest the evaluation of unintentional significant weight loss of 5% or more in 1 month or 10% in 6 months to be included in anthropometric assessments of nutritional status (Salva et al., 2009). Although anthropometric measurements may not be the most accurate methods of assessing nutritional status in older population, they are easy, quick and cheap to measure and form an essential part of the nutrition diagnosis component of the Nutrition Care Process.

A review by the task force on nutrition and aging of the International Association of Gerontology and Geriatrics and the International Academy of Nutrition and Aging has examined the literature for risk factors of malnutrition in long-term care facilities with residents age 65 years and older. Nutrition deficiency could result from inadequate mean energy intake at 1164 kcal per day. In terms of micronutrients, the majority of older adults in institutionalized settings have had multiple vitamins and minerals deficiencies (Salva et al., 2009). Even with sufficient macronutrient intakes, the levels of recommended micronutrient intake were not met in this population (Leydon & Dahl, 2008; Salva et al., 2009). Some factors that were associated with low BMI and weight loss in long-term care residents included old age, history of hip fractures,

depression, inadequate oral intake, inability to eat independently, presence of pressure ulcers, dysphagia and chewing disorders. Furthermore, leaving at least 25% of the main meal uneaten and the use of sedative drugs were predictors of weight loss. Older adults in long-term care homes with multiple diseases, such as dementia and depression, ADL dependence and drug and nutrient interactions, were associated with undernutrition. Behavioral changes in residents with dementia could alter eating patterns and contribute to weight loss. The environment of long-term care homes and food quality, including food flavor, variety, texture consistency and temperature, could significantly affect optimal nutrition intake among residents (Salva et al., 2009).

Nutrition recommendations in Europe for long-term care residents include optimizing food intake to provide sufficient energy and micronutrients. Energy requirement for residents are estimated to be between 30 to 35 kcal/kg of body weight per day. Protein recommendations should be targeted between 1.2 to 1.5 g/kg of body weight daily to account for changes in body protein distribution and metabolism (Salva et al., 2009). Current recommendations by the American Heart Association on dietary fat intake for healthy older adults are the same for the general population – fat intake of $\leq 30\%$ of calories from fat, limiting saturated fat to $<10\%$ of daily caloric intake and cholesterol to $<300\text{mg/day}$ (Krauss, Eckel, Howard, Appel, Daniels, Deckelbaum et al., 2000). No specific recommendations are made for older adults in institutionalized settings. However, a quantification of fatty acid intake among long-term care residents showed that dietary intake of α -linolenic acids (an essential fatty acid) was lower than the recommended levels of 1.6 g for men and 1.1 g for women by the Institute of Medicine. For the long chain omega-3 fats, eicosapentaenoic acid and docosahexaenoic acid, residents had an intake level of 70 mg, which was lower than the 500 mg daily recommended by the American Heart Association and Dietitians of Canada (Fratesi, Hogg, Young-Newton, Patterson,

Charkhazarin, Thomas et al., 2009). Furthermore, dysphagia and chewing difficulties should be addressed with speech and language therapists and thickening agents and pureed diets should be adopted when necessary. Foods presentation should optimize texture, taste, smell and color. Food flavor enhancement might be necessary to address taste and smell decline in order to optimize food intake. In addition, consideration of dining environment and staff-residents relationships has shown to decrease undernutrition risk and maintain quality of life in long-term care residents (Leydon & Dahl, 2008; Salva et al., 2009).

Although monitoring nutritional status is important for residents in long-term care homes, conducting nutrition screening is often challenging with different perceptions of malnutrition among health care workers. A study in New Brunswick has reported interviews of clinical dietitians, nurses and physicians on their perception of malnutrition in long-term care homes (Villalon, Laporte & Carrier, 2011). Only 63.5% of physicians interviewed believed that nutrition screening was important compared to 94.7% of nurses and 98.5% of dietitians who considered the screening to be an essential step. Furthermore, 78.6% of the dietitians reported that nutrition screening was done upon request in their workplaces. As a result of the underestimation of malnutrition, discrepancy in perceptions of malnutrition among health care professionals and the need of requisition procedures, the opportunity to identify patients entering long-term care homes at risk of malnutrition might be missed. Other challenges in performing nutritional screening at admission to long-term care homes included lack of time and insufficient material and human assistance for evaluation and treatment for residents at risk (Villalon et al., 2011). The lack of evidence-based practice and effective implementation of nutrition treatment made improvement of nutrition status difficult. Inconsistency of screening methods and the lack of using validated nutrition screening tools might also hinder accurate detection of malnutrition

(Bostrom et al., 2010; Villalon et al., 2011). In addition to differences in perception of malnutrition in long-term care facilities among health care workers, a lack of policies in nutrition care in long-term care might constitute part of the problems of malnutrition. The absence of regulations to ensure dietitian services, to assess dysphagia, to provide staff training and to ensure that residents receive nutritionally appropriate meals and standardized texture-modified foods could further exacerbates risks of malnutrition and worsen quality of life (Leydon & Dahl, 2008). Ensuring optimal nutritional status among residents in long-term care homes requires a multidisciplinary approach and attention to various aspects of residents' physiological and mental health.

2.4.5 Comorbidity

Long-term care residents often suffer from more than one chronic disease and atypical signs and symptoms can delay diagnoses and treatments (Heckman et al., 2013). A systematic review in the United States has shown higher number of morbidities to be associated with long-term care admission (Wang et al., 2013). In a study that examined different diseases and conditions in hospital-based long-term care homes in Ontario, multiple chronic diseases were prevalent in the residents, with the highest prevalence including hypertension (44.6%), cancer (27.6%), diabetes mellitus (25.9%), arthritis (25.3%), depression (21.4%) and dementia not Alzheimer's disease (18.8%) (Lam & Wodchis, 2010). Within the same sample, clinical conditions that were most prevalent include lack of balance (87.3%), ADL decline (58.4%), delirium (57.2%) and bowel (52.8%) and urinary (49.2%) incontinence. As a result, the presence of comorbidity could be related to a wide spectrum of health outcomes in long-term care home residents.

Long-term care residents with comorbidity are vulnerable to worsening disease prognosis and are prone to hospital admission. Among seniors in British Columbia, 5.3% of hospitalizations were older adults living in long-term care homes (Ronald, McGregor, McGrail, Tate & Broemling, 2008). The most frequent causes of hospitalization in this sample included femur fractures, pneumonia and heart diseases. Furthermore, hospitalizations due to femur fractures and pneumonia were higher in long-term care residents than community-dwelling older adults in all age groups whereas the latter had more hospitalizations related to heart disease (Ronald et al., 2008). The high prevalence of fractures suggests poor mobility and increasing frailty as significant risk factors of falls among residents. Pneumonia was the second leading cause of hospitalization among residents and may be related to aspiration due to tube feeding (Salva et al., 2008) and dysphagia (Labreche, Stolee & McLeod, 2011; Salva et al., 2008) causing pulmonary infections. Another factor that may lead to impaired mobility and physical functions (Labreche et al., 2011), and possibly hospitalization, was vision impairment. Within long-term care facilities, 61.8% of the residents suffered from cataracts and 42.6% experienced age-related macular degeneration. Visual problems seldom occurred individually – 65.9% of the examined residents had at least two visual impairments (Labreche et al., 2011). As a result of these multiple comorbidities, hospitalization might result in poorer health outcomes and additional mobility restriction could lead to worse quality of life and depression, thus resulting in a self-reinforcing cycle leading to poor overall health status among long-term care residents.

2.4.6 Functional Abilities and Frailty

Frailty is often parallel to functional ability with long-term care residents at the severe end of the spectrum. A review has shown ADL dependence to be a strong predisposing factor for long-term care admission (Luppa, Luck, Weyerer, Konig, Braehler & Riedel-Heller, 2010). Within

such setting, 75.6% of the residents have been found to be frail and the most severely frail individuals were completely dependent for ADL and/or were terminally ill (Matusik, Tomaszewski, Chmielowska, Nowak, Nowak, Parnicka et al., 2012). The high prevalence of frailty in this population with impaired mobility meant that these individuals were incapable of performing daily tasks independently themselves. Upon a follow-up of 12 months, residents who were most frail and cognitively impaired at baseline had a 50% chance of mortality, whereas those who were less frail and cognitively impaired had higher chance of survival. While frailty and cognitive impairment were considered separately for prediction of mortality, results were not statistically significant (Matusik et al., 2012). Therefore, the authors suggested that an interaction may exist between cognitive ability and functionality in the residents in which cognition status could affect physical abilities

Retaining mobility is crucial in maintaining quality of life and functional ability in long-term care residents. Poor vision (Labreche et al., 2011), fear of falling and weakness due to health problems (Chen, 2010) may limit walking. As a result, the use of mobility devices or walking aids increase with these conditions to maintain independence, self-autonomy and social engagement in long-term care residents. From the Canadian Study of Health and Aging between 1991 to 1995, 70.8% of the sampled residents required some sort of walking aids (Clarke, Chan, Santaguida & Colantonio, 2009). The proportion of wheelchair use was greater compared to walker or cane use. Among this sample, the prevalence of cognitive impairment (65.3%), arthritis (54.1%) and visual impairment (52.0%) were high. More than half of the sampled residents had walking difficulties. While examining risk factors associated with mobility aids use, it was found that chronic health problems and difficulties in ADL were significantly associated with increased mobility device use. Among all the factors, reported difficulty in

walking had the highest odds of requiring mobility devices. Those that used a cane or a walker had 90 times the odds of reporting walking difficulties than those who could walk independently whereas those using a wheelchair had 97 times the odds. Other factors that were significantly associated with mobility device use included history of fractures and breathing difficulties (Clarke et al., 2009). As a result, the use of mobility devices in long-term care homes were mostly triggered by the needs of the residents related to health problems and retained mobility could preserve their functional abilities.

Although mobility devices can assist residents' functional abilities, many factors present in long-term care can limit mobility, physical and functional activities. Under-utilized muscles may contribute further to worsening functional status. From a long-term care study in Ottawa, residents, relatives of residents and long-term care staffs believed that physical activity, especially mobility, was important for residents' physical and mental health (Benjamin, Edwards, Guitard, Murray, Caswell & Perrier, 2011). One of the most commonly perceived barriers to physical activities by stakeholders was inadequate support for physical activity. Financial funding was not sufficient to cover costs for staffing. Furthermore, residents preferred to perform physical activity with familiar staff instead of replacement staff because of the interrelationship and trust built between permanent staffs and the residents (Benjamin et al., 2011). With inadequate resources, physical activity programs were not usually customized to individual residents. As a result, residents might lose interest if the specific physical activity was not their preference. Another barrier to physical activity was the physical environment of the facility. The lack of space and exercise equipment hindered the ability to exercise, regardless of the residents' motivations. Narrow hallways, steep ramps and poorly lit areas might be conducive of a fall and thus residents' fear of falling could prevent physical activities entirely

(Chen, 2010). Lastly, supervised physical activities were preferred among residents; however, busy schedules and shortage of staff hindered supervised and safe physical activities. As a result, residents chose to avoid physical activities or were unable to exercise due to the lack of aids (Benjamin et al., 2011; Chen, 2010). In conclusion, the barriers to exercise were both personal and organizational. However, Chen (2010) argued that these barriers could be modifiable and Benjamin et al. (2011) suggested multi-level strategies to overcome these challenges.

Physical activity and exercise interventions could potentially improve or maintain functional abilities of long-term care residents for better health outcomes. Outcome measures of these physical activity interventions usually include independence in ADL, overall physical fitness and psychological wellbeing such as depression symptoms. A well-rounded exercise program in Japan consisted of resistance, aerobic and flexibility trainings for residents of long-term care for a total duration of 6 months, twice a week with each session about 30 minutes in length (Ouyang, Yatsuya, Toyoshima, Otsuka, Wada, Matsushita et al., 2009). Residents exhibited significant improvements in the hand manipulation and mobility components of the ADL score post-intervention. In terms of physical fitness, participants improved their walking distance within 6-minutes with better hand-eye coordination skills. Lastly, although results were not statistically significant, exercise intervention might have improved depression symptoms in this sample. The improvements observed in fitness might be accountable for the improvements of ADL components and strength training could be beneficial to functional abilities of the residents (Ouyang et al., 2009). However, the study examined a combination of exercises with resistance, aerobic and flexibility trainings; the three types of training might be synergistic to produce the observed benefits. Better depression symptoms might have also contributed to the improvements since, as mentioned previously, depression and residents' perception of health

could significantly affect health outcomes. Participation in the study might have caused residents to feel better about themselves thus resulting in better health status. In conclusion, physical activity could potentially maintain functional independence among long-term care residents. In addition to improvements in fitness level, physical activity could stimulate the residents' moods to elicit greater beneficial effects (Ouyang et al., 2009).

2.5 Hand Grip Strength

2.5.1 Overview

Loss of muscle strength has proven to be strongly associated with physical disabilities in older adults. Although muscle mass reduction has been commonly used to explain strength decline, decreases in muscle mass and strength have not always shown an association, thus suggesting that loss of muscle mass only partially explains muscle strength decline (Manini & Clark, 2012; Studenski, Peters, Alley, Cawthon, McLean, Harris et al., 2014). In contrast, hand grip strength is a widely used parameter to assess muscle strength and function in individuals. Factors affecting differences in hand grip strength include sex and age. Males are stronger than females in population studies and hand grip strength decline starts in the age 40's (Frederiksen, Hjelmborg, Mortensen, McGue, Vaupel & Christensen, 2006; Schlüssel, Anjos, Vasconcellos & Kac, 2008). Hand grip strength has been recommended as a tool to assess nutritional status (Alvares-da-Silva & Silveira, 2005; Matos, Tavares & Amaral, 2007; Peng, Plank, McCall, Gillanders, McIlroy & Gane, 2007; Soeters, Reijven, Schueren, Schols, Halfens, Meijers et al., 2008; Vaz, Thangam, Prabhu & Shetty, 1996). Decreased hand grip strength has also been found to be associated with cognitive impairment in older adults (Auyeung et al., 2011; Huh, Yang, Lee, Lim, Kim & Paik, 2011; Fried et al., 2001; Samper-Ternent et al., 2012). Furthermore, it predicts mortality (Rantanen, Volpato, Ferrucci, Heikkinen, Fried & Guralnik, 2003), post-

operative complications (Klidjian, Foster, Kammerling, Cooper & Karran, 1980) and risk of ADL dependence (Rantanen, Avlund, Suominen, Schroll, Frandin & Era, 2002) or functional limitations (Bohannon, 2008; Rantanen, Guralnik, Foley, Masaki, Leveille, Curb et al., 1999). The use of hand grip strength to assess functional performance in older adults is therefore very appealing because of its potentially wide application.

Compared to other muscle strength parameters commonly used and recommended, such as knee extension strength, hand grip strength is a test that is easy to measure with simple training. The method is also inexpensive (Frederiksen et al., 2006; Lauretani et al., 2003; Schlussek et al., 2008), thus often preferable in research and more feasible in clinical studies (Cruz-Jentoft et al., 2010). An argument against generalizing the use of hand grip strength to lower extremity muscle strength and function is that components beyond strength are involved in the determination of balance and mobility (Norman et al., 2010). However, hand grip strength is closely correlated to knee extension strength (Lauretani et al., 2003; Norman et al., 2010). Various statistical analyses have resulted in high correlation between the two parameters, with Pearson correlation $r=0.55-0.89$ and Cronbach's alpha $r=0.88$ (Bohannon, 2012). Furthermore, sarcopenia is thought to be a systemic condition (Lauretani et al., 2003) and thus justifies the use of hand grip strength as a measure of overall muscle strength.

Different methods and instruments exist in practice to measure hand grip strength. A review of the literature evaluated the variations in methods of using hand grip strength (Roberts, Denison, Martin, Patel, Syddall, Cooper et al., 2011). The most widely used dynamometer to measure grip strength in the literature with the largest number of normative data available is the Jamar hand dynamometer. It has also been validated against other dynamometers to produce reliable inter-instrument results. It is a portable device which contains a sealed hydraulic system

to allow measurements to be read off a gauge dial. Other types of devices that measure grip strength include: 1) the mechanical dynamometers which measure the amount of tension produced in a spring and, 2) the strain dynamometers which measure electrical resistance of a length of wire due to the strain applied to the device. Although the hydraulic dynamometer is the most commonly used device in the literature, it may not be suitable for individuals with weak joints. Also, the device requires at least 3-4 lbs to produce a measurement, thus it may be unsuitable for weak individuals due to greater reading errors at lower strengths (Roberts et al., 2011).

The standard protocol by the American Society of Hand Therapists for performing grip strength test is to have the subject seated, shoulders neutrally rotated with elbow flexed at 90° with forearm in neutral position. The most commonly used measurement protocol is to perform three consecutive trials, and average the values to produce a single grip strength value (Roberts et al., 2011). However, it has been shown that using either the average value or the maximum value of the three consecutive measurements produced no significant difference (Haidar, Kumar, Bassi & Deshmukh, 2004). Grip strength has also been shown to have high test-retest reliability with correlation coefficients of 0.91 and 0.95 for right and left hands, respectively, in community-dwelling older adults (Bohannon & Schaubert, 2005; Roberts et al., 2011). The inter-tester reliability of hand grip was $r=0.98$ for both hands among healthy volunteers (Peolsson, Hedlund & Oberg, 2001).

2.5.2 Reference Values for HGS

Nutritional assessment and screening tools require normative values for clinical measurements to compare against a reference value. A cut-off value for hand grip strength is required to define a threshold in which below it indicates a risk of malnutrition or functional

disability (Studenski et al., 2014). National surveys, such as the Canadian Health Measures Survey in 2007-2009, have gathered grip strength of community-dwellers across the country from age 7 to 69 years. Among the age groups of 20-39 years, 40-59 years and 60-69 years, hand grip strength significantly decreased with increasing age. Within individuals between ages 60-69 years, the total left and right grip strength was 81kg for males and 48kg for females (Shields, Tremblay, Laviolette, Crag, Janssen & Gorber, 2010). However, results for older adults age ≥ 70 years from national data were not available for analysis.

From a pooled cross-sectional study, the Foundation for the National Institutes of Health Sarcopenia Project has validated hand grip strength against slow walking speed of < 0.8 m/s as a marker of clinical weakness (Alley, Shardell, Peters, McLean, Dam, Kenny et al., 2014; Studenski et al., 2014). The study pooled nine epidemiology studies with older adults age ≥ 65 years and reported hand grip strength to range from 27.6-41.6 kg for men (average 39.7 kg) and 15.8-23.7 kg for women (average 20.5 kg) (Studenski et al., 2014). From the analysis, men with grip strength < 26 kg and women with strength < 16 kg were identified as clinically weak with 7.62 and 4.42 times, respectively, more likely to walk slow (Alley et al., 2014). The group further defined normal strength as ≥ 32 kg in men and ≥ 20 kg in women and intermediate strength as 26-31.9 kg and 16-19.9 kg, respectively. However, the pooled samples included relatively healthy participants who were community-dwellers (Alley et al., 2014) and the mean age was 75.2 years for men and 78.6 years for women (Studenski, et al., 2014), and thus data may not be generalizable entirely to older and frailer population. Other studies have also examined normative values and results were comparable to the cut-off strength for clinical weakness. Lauretani et al. (2003) have suggested the values of 30 kg in men and 20 kg in women for discrimination of mobility limitation. Another study has identified cut-off values based on

BMI (Cruz-Jentoft et al., 2010; Fried et al, 2001). Definition of cut-off values help in identification of at risk individuals during screening for early intervention.

Most reference values for hand grip strength are obtained from younger populations, but data for the older portion of the population are harder to analyze as most community-based studies have categorized the older olds (≥ 85 years) into one group for analysis (Gunther, Burger, Rickert, Crispin & Schulz, 2008; Luna-Heredia, Martin-Pena & Ruiz-Galiana, 2005) due to small sample size. To address this issue, a meta-analysis has examined the literature for grip strength among older adults between the ages of 75-99 years (Bohannon, Bear-Lehman, Desrosiers, Massy-Westropp & Mathiowetz, 2007). Bohannon et al. (2007) have examined hand grip strength across four old age groups – 75-79 years, 80-84 years, 85-89 years and 90-99 years. However, with the small sample of participants aged 90-99 years, it may not be generalizable over the rest of the population (Bohannon et al., 2007) and it might reflect a selection effect of survival. Summary of hand grip strength and cut-off values from different studies is presented in Table 2.3 and 2.4.

Table 2.3 Summary of Average Hand Grip Strength (kg)

Study	PNAFS		NWAHS		Bohannon et al. (2007)	
	Male	Female	Male	Female	Male	Female
20-29	44.8	26.4	46.0	29.0	-	-
30-39	45.5	27.4	47.0	30.0	-	-
40-49	42.4	26.4	46.0	28.5	-	-
50-59	40.0	23.6	44.0	27.0	-	-
60-69	35.6	21.6	49.0	23.5	-	-
≥70	30.6	16.8	32.5	19.5	-	-
75-79	-	-	-	-	32.1	20.5
80-84	-	-	-	-	28.6	17.2
85-89	-	-	-	-	25.5	16.4
90-99	-	-	-	-	18.9	15.0

Abbreviations: PNAFS: Nutrition, Physical Activity and Health Survey (Schlüssel et al., 2008);
NWAHS: North West Adelaide Health Study (Massy-Westropp, Gill, Taylor, Bohannon & Hill, 2011)

Table 2.4 Summary of Hand Grip Strength (kg) Cut-off Values

CHS ¹				FNIH ²			InCHIANTI ³		
BMI*	Male	BMI*	Female	BMI	Male	Female	BMI	Male	Female
≤24.0	≤29	≤23.0	≤17	N/A	<26	<16	N/A	< 30	< 20
24.1-26.0	≤30	23.1-26.0	≤17						
26.1-28.0	≤30	26.1-29.0	≤18						
>28.0	≤32	>29.0	≤21						

Abbreviation: CHS: Cardiovascular Health Study (Fried et al., 2001); FNIH: Foundation for the National Institutes of Health Sarcopenia Project (Alley et al., 2014); InCHIANTI: Invecchiare in Chianti (Lauretani et al., 2003); N/A: Not Available

¹ Based on definition of frailty

² Based on walking speed <0.8 m/s

³ Based on walking speed <0.8 m/s and difficulty walking 1km

* Unit in kg/m²

2.5.3 Nutritional Status

Decrease in muscle strength among the elderly may be partially attributable to poor nutritional status. Weakness may be a result of reduced muscle mass (Studenski et al., 2014), which has been shown to be related to protein and energy malnutrition in older adults (Kaiser et al., 2010). Various studies have compared established nutritional assessments with hand grip strength. The Nutritional Risk Screening is recommended by the European Society for Clinical Nutrition and Metabolism to detect undernutrition and its risk (Matos et al., 2007). It was shown that patients with lower hand grip strength had higher odds of being nutritionally at risk. When the lowest strength quartile was used as a diagnostic cut off level for undernutrition risk, it showed comparable diagnostic results with the Nutritional Risk Screening (Matos et al., 2007). Similar results were found using the SGA. Hand grip strength was significantly lower in patients who were classified as severely malnourished compared to those that were well nourished (Norman et al., 2010). The authors concluded malnutrition to be a significant risk factor for reduced hand grip strength. Interestingly, hand grip strength has been shown to distinguish chronically energy-deficient individuals from those that were underweight but well nourished (Vaz et al., 1996). Both groups of individuals had $BMI < 18.5 \text{ kg/m}^2$, but chronic malnourished subjects had significantly lower grip strength than underweight individuals. Furthermore, muscle area was not statistically different between the groups but grip strength difference remained significant after adjusting for covariates (Vaz et al., 1996). Thus, nutritional status could be a potential determinant of hand grip strength.

2.5.4 Protein Intake

Protein malnutrition has often been specifically examined as a potential contributing factor to reduced strength. Cachexia – the wasting of protein and energy stores related to chronic

diseases – is often related to loss of lean muscle mass (Messinger-Rapport et al., 2013), which may further lead to reduction of strength (Studenski et al., 2014). Specifically, hand grip strength was found to be significantly lower among protein depleted liver cirrhotic patients compared to non-protein depleted subjects (Peng et al., 2007). The authors did not control for disease severity across the groups, but previous analysis showed no significant difference in hand grip strength between disease severity assessed by Child-Pugh score. Another study showed low hand grip strength to be associated with low protein intake in non-frail, community dwelling postmenopausal women (Filion, Barbat-Artigas, Dupontgand, Fex, Karelis & Aubertin-Leheudre, 2012). This subgroup of women's protein intake level was at or slightly above the Recommended Dietary Allowance (RDA) level of 0.8-1.2g/kg body weight whereas those with strong grip strength had higher protein intake level at 1.4g/kg body weight. The authors suggested that higher protein intake level beyond the current recommended level may warrant maintenance of muscle strength in older adults. However, an intervention trial examining the effects of protein- and energy-enriched diet on muscle strength in nursing home residents for 12 weeks has shown no improvement (Smoliner, Norman, Scheufele, Hartig, Pirlich & Lochs, 2008). In this study, the treatment group reached a protein intake level of 1.3g/kg body weight by the end of the intervention; however, hand grip strength remained the same as the control group. The reason for such outcome may be two-folds. First, as mentioned by Filion et al., protein intake level at the RDA may be insufficient to improve muscle strength in elderly. Secondly, the participants in the intervention trial were nursing home residents with higher degree of frailty compared to community-dwelling individuals (Smoliner et al., 2008); thus the required protein intake level may even be higher than those needed by healthy subjects to maintain muscle

strength. As a result, sufficient protein intake level could potentially be essential for the maintenance of hand grip strength among older adults.

2.5.5 Vitamin D

Vitamin D status is measured by the serum levels of 25-hydroxyvitamin D (25(OH)D). It has been studied to examine its relationship with muscle strength; however, controversies on the relationship exist among different studies. The association of muscle strength and serum 25(OH)D appears to have a non-linear relationship (Stockton, Mengersen, Paratz, Kandiah & Bennell, 2011). A study examining subjects age 21-97 years found no difference in hand grip strength across serum 25(OH) D levels, averaging 57nmol/L and 55nmol/L in men and women, respectively (Marantes, Achenbach, Atkinson, Khosla, Melton III & Amin, 2011). However, considering only women age ≥ 65 years (mean serum 25(OH)D of 52nmol/L) in the same study, hand grip strength was negatively associated with serum 25(OH)D, with greatest strength at serum levels of 12.5-40nmol/L, followed by 42.5-52.5nmol/L, 55-67.5nmol/L and 70-170nmol/L. The similar phenomenon is observed between frailty and serum 25(OH)D. In comparison of frailty status with serum 25(OH)D, the lowest risk of frailty was associated with lower serum 25(OH)D level of 50-75nmol/L but levels ≥ 75 nmol/L were associated with higher risk of frailty (Rizzoli, Boonen, Brandi, Bruyere, Cooper, Kanis et al., 2013). These results showed beneficial effects of serum 25(OH)D at levels up to 75nmol/L but no hand grip strength and frailty improvements were observed at levels reaching the higher limit.

In contrast to the observed non-linear relationship of grip strength and vitamin D, two other studies on community dwelling older adults (age ≥ 65 years) with defined vitamin D insufficiency (serum 25(OH)D < 50 nmol/L) were found to have significantly lower hand grip strength (Menant, Close, Delbaere, Sturnieks, Trollor, Sachdev et al., 2012; Shardell, D'Adamo,

Alley, Miller, Hicks, Milaneschi et al., 2012). However, a study on community dwelling women with an average age of 60 years found no significant difference in hand grip strength across serum 25(OH)D tertiles (Moschonis, Tanagra, Koutsikas, Nikolaidou, Androustos & Manios, 2009). The difference might be due to variation in age; however, statistical analyses were also different. Both studies by Menant et al. (2012) and Shardell et al. (2012) used 25(OH)D below and above 50nmol/L to define vitamin D insufficiency and sufficiency, respectively; whereas Moschonis et al. (2009) compared hand grip strengths across three levels of 25(OH)D (25.25-52.75nmol/L, 52.75-77.5nmol/L, and 77.5-118.75nmol/L) . When serum vitamin D was expressed as a continuous variable, higher serum 25(OH)D was significantly associated with higher hand grip strength (Moschonis et al., 2009). In another study, an examination of serum 25(OH)D and hand grip strength at baseline has found similar trend using different serum vitamin D cut off values (Houston, Tooze, Davis, Chaves, Hirsch, Robbins et al., 2011). After adjustment for body weight, individuals with vitamin D deficiency (<50nmol/L) and insufficiency (<75nmol/L) had significant lower hand grip strength than those with vitamin D sufficiency (\geq 75nmol/L). Regardless of the variations in vitamin D status cut off values, there is an association of low serum level with weaker grip strength.

In addition to observational studies on the association of vitamin D status and hand grip strength, intervention trials have examined the effect of vitamin D supplementation on grip strength improvement. Overall musculoskeletal functions incorporating hand grip, knee extensor and knee flexor strengths have significantly improved with supplementation of calcium and 800 IU (International Units) of vitamin D daily for 3 months in institutionalized individuals with baseline median 25(OH)D at 30nmol/L (Bischoff et al., 2003). A meta-analysis of randomized controlled trials of vitamin D treatment with or without calcium presented some caveats. No

muscle strength improvement was observed with vitamin D treatment in replete subjects with baseline serum 25(OH)D > 25nmol/L (Stockton et al., 2011). A recent systematic review of vitamin D intervention has found similar results in which hand grip strength in the treatment group was not significantly different from the control group (Muir & Montero-Odasso, 2011). In this review, the baseline serum 25(OH)D was greater than 25nmol/L as well, which was in agreement with results obtained by Stockton et al. (2011). Thus, serum 25(OH)D may reach a saturation effect at certain level which no further strength improvement is observed (Muir & Montero-Odasso, 2011; Stockton et al., 2011).

With the abundance of vitamin D receptors across various body tissues, the effects of vitamin D are not limited to skeletal muscles. Vitamin D has been shown to be associated with frailty, balance and fall (Dawson-Hughes, 2012). A prospective study by Menant et al. (2012) on community-dwelling older adults with vitamin D insufficiency (mean 25(OH)D of 36.5nmol/L) exhibited slower reaction time and lower executive function score at baseline. In addition, intervention with calcium and vitamin D resulted in fall reduction compared to control group with calcium only (Bischoff et al., 2003). The post-intervention median serum 25(OH)D level of this study was 66nmol/L in the treatment group compared to 28 nmol/L in the control group. These findings could be related to the effect of low vitamin D on poorer neuropsychological function among fallers. However, a 1-year follow up by Menant et al. (2012) comparing fallers and non-fallers found no difference in mean serum 25(OH)D levels at 60nmol/L and 63nmol/L, respectively. The observed effect of fall reduction could be a result of the change in serum vitamin D level, instead of the serum 25(OH)D status; although an elevated serum vitamin D status is still required to prevent fall (Muir & Montero-Odasso, 2011). The significant improvements in balance sway and timed up & go test with vitamin D supplementation, but not

hand grip strength, at higher baseline vitamin D status suggest a stronger neural effect than an effect on strength (Muir & Montero-Odasso, 2011) and there may be a saturation effect on strength at higher serum 25(OH)D dose.

2.5.6 Depression and HGS

Depression is a common geriatric syndrome that affects older adults with comorbidity. Frailty and weakness in older adults often coexist with depression. Among a group of Dutch older adults, frailty was prevalent (27.2%) in individuals who were depressed, which was significantly higher ($P < 0.001$) than those that were not depressed (9.1%) (Collard, Comijs, Naarding & Voshaar, 2014). Within the subsample of depressed individuals, those with low grip strength had 1.02 times ($P = 0.025$) higher chance of experiencing more severe depression. In particular, weakness was significantly associated with the mood and anxiety/arousal of an individual (Collard et al., 2014). From a secondary data analysis of a randomized controlled trial in hospitalized patients, patients with sarcopenia, as defined according to the definitions of the European Working Group, had significantly more depressive symptoms compared to those who were non-sarcopenic (Gariballa & Alessa 2013). Since there are overlaps between the definition of frailty and sarcopenia, associations of depression with the two conditions are not surprising. However, it is important to note that functional disability due to frailty and weakness may contribute to depressive symptoms and vice versa, resulting in a self-reinforcing cycle.

Depression is not only associated with frailty and muscle weakness, but it is also related to functional disability. Among hospitalized patients with hip fractures due to a fall, depressive symptoms were more common among individuals with low grip strength (Savino, Martini, Lauretani, Pioli, Zagatti, Frondini et al., 2013). In this study, post-surgical recovery was defined as being able to walk. Patients with greater grip strength at baseline had higher odds of an

incidental event of walking post-surgically; whereas patient with greater depression had lower odds of an incidental walking event. However, the association of depression and persistent walking (more than one walking event) was not significant (Savino et al., 2013). Greater strength may be beneficial for recovery; however, the presence of depression may attenuate the recovery process. From another cross-sectional study examining physical performance and geriatric syndromes in Japanese women, hand grip strength was able to identify depressed individuals with acceptable degree of discrimination. Furthermore, women with grip strength <17.3 kg in this study were 2.8 times more likely to experience depression (Seino, Yabushita, Kim, Nemoto, Jung, Osuka et al., 2013). The link between depression and strength is unknown because of a wide range of symptoms involved. The poorer strength performance may also be related to individual's mood at the time of performance so that the measurement might not truly reflect maximal strength.

2.5.7 Cognition and HGS

Poor cognition status and frailty often occur simultaneously in older population. From the CHS and the Hispanic Established Population for the Epidemiological Study of the Elderly, frail individuals were found to have significantly lower MMSE score than non-frail individuals (Fried et al 2001; Samper-Ternet et al., 2012). In a cohort of over 16 years with older adults age 65 years and above, individuals who were frail at baseline, defined by the CHS algorithm, had an incidence of 54.6 per 1,000 person-year for developing dementia compared to a rate of 29.3 per 1,000 person-years for those who were not frail. The hazard ratio of baseline frailty for developing non-Alzheimer's disease dementia was 2.57 (95% CI 1.08-6.11), but results were not significant for Alzheimer's disease (Gray, Anderson, Hubbard, LaCroix, Crane, McCormick et al., 2013). It may be that frailty and cognitive decline coexist but share different

pathophysiological processes and thus not necessarily associated (Mhaolain, Gallagher, Crosby, Ryan, Lacey, Coen et al., 2011).

Cognitive decline has also been a commonly studied variable to be associated with muscle strength decline (Auyeung et al., 2011; Fried et al., 2001; Samper-Ternet et al., 2012). Reductions in muscle strength, such as knee extensor (Huh et al., 2011) and hand grip strength (Auyeung et al., 2011), were shown to be associated with cognitive flexibility decline. Using the MMSE to assess cognitive functioning, subjects with lower hand grip strength were associated with lower MMSE score (Auyeung et al., 2011). A systematic review on older adult age ≥ 65 years found that weaker grip strength at baseline was associated with higher subsequent risk of cognitive decline (Cooper, Kuh, Cooper, Gale, Lawlor, Matthews et al., 2011). Among a sample of Korean women, significantly lower grip strength was associated with presence of dementia, especially in the older and weaker females who had higher prevalence of dementia (Shin, Kim, Kim, Shin & Yoon, 2012). Grip strength was significantly associated with dementia with an odds ratio of 1.59 in this sample. However, as mentioned previously, signs and symptoms in older adults often overlap (McCusker et al., 2014; Scarmeas, Albert, Brandt, Blacker, Hadjigeorgiou, Papadimitriou et al., 2005). Symptoms unrelated to cognitive impairment in individuals may also result in muscle weakness. As a result, Cooper et al. (2011) suggested that grip strength may only detect general health status, instead of presence or absence of specific health condition.

In the current literature, population-based studies on hand grip strength have often excluded participants with cognitive impairment because of measurement reliability uncertainty. However, studies have shown that hand grip strength among individuals with dementia had high test-retest reliability (Alencar, Dias, Figueiredo & Dias, 2012; Blankevoort, van Heuvelen & Scherder, 2013). Alencar and colleagues (2012) used the Clinical Dementia Rating to classify

MMSE scores and test-retest reliability for borderline ($r=0.975$), mild ($r=0.968$) and moderate ($r=0.964$) dementia was excellent. However, those with severe dementia had low test-retest reliability ($r=0.415$) for grip strength over a one-week period (Alencar et al., 2012). Another study showed similar results using the MMSE – grip strength had an intra-class correlation coefficient (ICC) $r=0.90$ for test-retest reliability among individuals with dementia. Over a one-week period, $r=0.86$ for mild cognitive impairment (MMSE score = 20-28) and $r=0.94$ for moderate impairment with MMSE score = 10-19 (Blankevoort et al., 2013). As a result, grip strength may still be valid for participants with mild to moderate cognitive impairment, but results must be interpreted with caution for patients with severe cognitive impairment.

2.5.8 Disease Complications and HGS

The applications of hand grip strength are widespread. It is often used to predict future health outcomes. In clinical trials, hand grip strength has been shown to be a significant predictor of post-operation complication, disease severity and mortality in patients. In a study by Klidjian et al. (1980), nutritional measurements such as hand grip strength, arm muscle circumference and plasma albumin concentration of patients were made prior to abdominal operations. Pre-operative hand grip strengths below 85% of a healthy reference population were most predictive of post-operative complications. Hand grip strength was also the most sensitive method of predicting complications in patients after undergoing surgery (Klidjian et al., 1980). Another study on hospital inpatients have found subjects with lower hand grip strength to have longer length of hospital stay, but results were not statistically significant after adjustment for age, height, sex and disease severity (Matos et al., 2007). Furthermore, hand grip strength is also associated with disease severity among liver cirrhosis patients (Peng et al., 2007). In this study, men with more severe liver cirrhosis with Child-Pugh score B or C ($36.2 \pm 1.3\text{kg}$ and $35.1 \pm$

1.4kg, respectively) had significantly weaker grip strength than those with score A (41.2 ± 1.1 kg; $P < 0.05$). In conclusion, low hand grip strength tends to be observed in severer disease cases, resulting in higher chance of complications and longer length of stay in hospital.

In addition to disease complications, hand grip strength is also correlated with patient mortality. Among patients with cardiovascular and respiratory diseases, lower hand grip strength was associated with higher mortality rates. Patients with cardiovascular disease in the lowest hand grip strength tertile had 2.2 times higher risk of mortality compared to those in the higher strength tertile (Rantanen et al., 2003). Therefore, the relationships of hand grip strength with disease severity and mortality are often interrelated. For example, in a 1-year follow up with liver cirrhosis patients, individuals who were considered as malnourished according to low baseline grip strength had significantly higher incidence of complications than those that were categorized as well-nourished by the strength marker (Alvares-da-Silva & Silveira, 2005). In the same study, mortality was only found in the malnourished group defined by low hand grip strength. This adds to the significance of the variable in pinpointing malnutrition in a disease which nutritional status plays a critical role (Alvares-da-Silva & Silveira, 2005). However, although the association of muscle strength and mortality is promising, the mechanism of such correlation in terms of inflammation, malnutrition, low physical activity and depression in patients with comorbidity is still uncertain (Rantanen et al., 2003).

2.5.9 Exercise and HGS

It may be intuitive to assume that exercise and training could result in better hand grip strength. However, research on exercise and hand grip strength shows mixed results. From a longitudinal 22-year follow up study, individuals who performed strenuous work-related physical activity had a greater decline of grip strength compared to those who had light work-

related physical activity (Stenholm, Tiainen, Rantanen, Sainio, Heliovara, Impivaara et al., 2012). However, the same study has shown that individuals who adopted a sedentary lifestyle from a physically active lifestyle during the follow up period experienced greater reduction in grip strength. A cross-sectional study that examined the association of grip strength and exercise questionnaire in older adults found greater strength to be associated with higher activity score (Logan, Gottlieb, Maitland, Meegan & Spriet, 2013). The questionnaire assessed the frequency, duration and intensity of activities such as walking, exercise, housework, recreational activities, gardening and caring for others. However, the authors concluded that the score should not be used to predict health outcomes due to low correlative capacity (Logan et al., 2013). A twelve-week Education, Self-Management, and Upper Extremity Exercise Training for People with Rheumatoid Arthritis (EXTRA) provided 4 global upper extremity exercise training sessions supplemented with patient self-managed home exercise with therapeutic putty and elastic resistance bands (Manning, Hurley, Scott, Coker, Choy & Bearne, 2014). Subjects were randomized into the EXTRA program or the usual care group. The overall mean age of the participants was 55 years with diagnosis of rheumatoid arthritis for less than 6 years. After twelve weeks, non-dominant hand grip strength from the EXTRA program group was significantly stronger than those who received usual care. However, the benefits did not persist over a longer period of 36 weeks (Manning et al., 2014). A meta-analysis of randomized controlled trial of the efficacy of resistance bands training to improve grip strength in diabetic patients showed no significant effect (McGinley, Armstrong, Boule & Sigal, 2014). Thus, results suggest that strength needs to be maintained in order to be prolonged and improvements depend on the types of exercise.

Other studies in the literature showed promising results of exercise on hand grip strength improvement. An eight-week training program on older adults with dementia showed improvements of hand grip strength (Cadore, Moneo, Mensat, Munoz, Casas-Herrero, Rodriguez-Manas et al. 2014). The program consisted of an initial gait and cognitive training, with resistance training introduced at the fourth week since commencement for another 4 weeks. Gait and cognitive training showed no improvement but resistance training significantly resulted in greater strength. However, grip strength decreased after 12 weeks post-intervention to a level significantly lower than baseline value. The results suggested that frail adults with dementia retained their capacity to improve strength with exercise but the intervention must be maintained for the observed effects to last longer (Cadore et al., 2014). Twenty-four weeks of aquatic exercise for postmenopausal women also significantly improved hand grip strength as an outcome endpoint. The aquatic resistance may be similar to resistance training with high intensity (Moreira, Fronza, dos Santos, Teixeira, Krueel & Lazaretti-Castro, 2013). In conclusion, exercise that incorporates strength training may be more beneficial to improved hand grip strength than without training and training must be sustained for longer-lasting benefits.

2.6 Activity of Daily Living and Functional Assessment

2.6.1 Overview

The validity of hand grip strength used as an assessment tool is often compared to other functional markers, such as the activity of daily living score, since it is a simple and objective functional measurement. Several ADL evaluation tools are currently used in the literature including the Katz Index, the Older American Resource Services (OARS) Activities of Daily Living Scale and the Barthel index. The OARS Activities of Daily Living Scale includes two categories of functional status. The basic ADL elements include eating, dressing, taking care of

own appearance, walking, transferring from bed, bathing and using the toilet. The instrumental ADL includes the ability to use the phone, to travel, to shop, to complete housework, to take medications and to attend to financial tasks (Dal Bello-Haas, Thorpe, Lix, Scudds & Hadjistavropoulos, 2012; Fillenbaum, 1988; Franke, Margrett, Heinz & Martin, 2012; Thomas, Rockwood & McDowell, 1998). Many other studies use a modified version of these ADL evaluation tools to assess functional ability and falls (Diehr, Thielke, Newman, Hirsch & Tracy, 2013; Olsson Moller, Midlov, Kristensson, Ekdahl, Berglund & Jakobsson, 2013; Rantanen et al., 2002).

Hand grip strength is often used to predict other functional limitations. For example, hand grip strength was used to assess the risk of developing mobility limitation based on patients' walking ability and speed (Marsh, Rejeski, Espeland, Miller, Church, Fielding et al., 2011; Rantanen et al., 1999; Sallinen, Stenholm, Rantanen, Heliovaara, Sainio & Koskinen, 2010) and ability to rise from a chair without using hands (Rantanen et al., 1999; Sabol, Resnick, Galik, Gruber-Baldini, Morton & Hicks, 2011). As a result, hand grip strength is applicable in predicting a wide range of functional limitations.

2.6.2 ADL Scores and Hand Grip Strength

Hand grip strength measurements are often used to predict subsequent activity of daily living dependence in older adults. A longitudinal study with initially ADL independent community-dwelling 75-year old adults examined the relationship of baseline HGS and the onset of ADL dependence after 5-years follow up (Rantanen et al., 2002). Both men and women who became ADL dependent at follow up had lower baseline HGS than those who remained ADL independent. Furthermore, subjects in the lowest and middle HGS tertiles were 2.3 (95% CI: 1.04-5.07) and 1.29 (95% CI: 0.58-2.87) times, respectively, more likely to develop ADL

dependence after 5 years (Rantanen et al., 2002). Another population-based study in adults age 40-80 years examined baseline hand grip strength and ADL dependence after 10 years (den Ouden, Schuurmans, Brand, Arts, Mueller-Schotte, S. & van der Schouw, 2013). After adjusting for age, sex and other covariates, higher baseline hand grip strength was significantly associated with lower relative risk, RR=0.72 (95% CI: 0.57-0.92) of developing ADL disability after ten years. Therefore, greater strength might act as a reserve before it declined below a threshold level in which ADL disability was observed (Rantanen et al., 2002) and further led to physical disability such as difficulty in balancing, walking and rising from a chair (den Ouden et al., 2013).

In order to draw further insight into the relationship of HGS and ADL, the rate of decline for both HGS and ADL dependence in older adults are examined. In a population-based study of older adults at age 85 years, HGS decline was used to predict decline in ADL independence annually (Taekema, Gussekloo, Maier, Westendorp & De Craen, 2010). ADL scores ranged from 9 points to 36 points, with higher score being more ADL dependent. Poorer HGS was associated with worse ADL score at baseline ($P<.001$). After 4 years of follow up, the annual increase of ADL dependence was 1.28 points ($P<.001$) in participants with mean HGS level, adjusted for sex, height, weight and income. It was also estimated that ADL dependence score increased by 0.02 point ($P<.001$) for every 1 kg reduction in HGS. Thus, subjects with lower baseline HGS had greater ADL dependence increment over the study period (Taekema et al., 2010). Similarly, another longitudinal study has examined 5-year changes in standardized health indicators in older adults age 65 years and above (Diehr et al., 2013). The use of standardized scores allowed for comparisons of health indicators with different grading scale. Among the 13 measurements of health examined, ADL independence was among the ones with greatest decline

over the study period. Reduction in mean standardized ADL and HGS were -16.2 and -14.6, respectively, and the rates of decline significantly differ ($P=.05$). Furthermore, men had greater decline in both measurements than women, regardless of age (Diehr et al., 2013). Although HGS is a good predictor of ADL dependence onset, the different decline rates may be due to varying strength requirements of ADL items that are not necessary for grip strength performance.

HGS was also found to significantly predict different ADL items. From a 25-year prospective study, baseline HGS was measured in men from age 45-68 years and ADL items were assessed at follow up visits (Rantanen et al., 1999). ADL items included ability to dress, bath, eat, use the toilet and walk. Baseline HGS was divided into lowest, middle and highest strengths. Lowest and middle strengths men had the highest significant odds of developing disability in dressing (lowest: OR=2.43 with 95% CI: 1.42-4.15; middle: OR=1.65 with 95% CI: 1.01-2.71), followed by bathing (lowest: OR=2.06 with 95% CI: 1.18-3.59; middle: OR=1.76 with 95% CI: 1.07-2.92); whereas abilities in eating and using the toilet did not significantly differ among different strength levels (Rantanen et al., 1999). Varying incidences of disability among ADL items were also observed in the older population. Dressing was found to have the greatest incidence of disability in a population of older adults age 60 years and above (Alexandre, Corona, Nunes, Santos, Duarte & Lebrao, 2012). The authors suggested that dressing requires upper body strength, flexibility and balance and may indicate early onset of disability. As a result, HGS as a screening tool for specific ADL items warrant early detection and prevention of disability in older adults.

2.6.3 Functional Limitations and Hand Grip Strength

HGS is also used to predict functional limitation in the future in older adults. In a group of centenarians (mean age of 101.0 years old), baseline HGS was a significant predictor of

functional components after a 6-month follow up (Franke et al., 2012). Significant correlation was found between higher HGS with greater upper body functioning ($r=0.69$, $P<0.01$), greater lower body functioning ($r=0.65$, $P<0.05$) and greater advanced lower body functioning ($r=0.66$, $P<0.05$), which included activities that required more strength and endurance (Franke et al., 2012). A cross-sectional study in nursing home residents found stronger grip strength to significantly correlate (0.213 , $P=0.01$) with the ability to rise from a chair as a functional measurement (Sabol et al., 2011). From multivariate analysis, residents with stronger strength had higher odds of 1.115 (95% CI: $1.060-1.174$) of rising from a chair compared to those with weaker grip strength (Sabol et al., 2011). These studies illustrate that stronger grip strengths warrant greater functional abilities in older adults.

In addition, mobility limitation was a common functional variable to assess the use of hand grip strength measurements. Hand grip strengths below BMI-specific cut-off values in men and women age 55 years and above were found to have greater odds (OR for men= 2.73 , 95% CI: $1.91-3.88$; OR for women= 2.73 , 95% CI: $2.10-3.54$) of reported difficulties in walking 500m (Sallinen et al., 2010). From a study of community-dwelling older adults of age 70-89 years, there was a significant gradient of increasing mobility limitation with decreasing hand grip strength quartiles ($P<0.001$) at baseline (Marsh et al., 2011). In this study, mobility limitation was defined as the inability to walk 400m within 15 minutes. Compared to the highest strength quartile, lowest strength quartile individuals had 6.11 times ($P<.001$) higher risk of developing mobility disability at follow up visits (Marsh et al., 2011). Regardless of the different mobility outcome variables of the studies, there is comparable trend in lower hand grip strength with lower degree of mobility in older adults.

CHAPTER 3 METHODS

3.1 Study Design

The present study used data available at the time of analysis from the research study: The effects of a walking program on balance, falls and well-being in individuals residing in long-term care. The detailed study protocol has been published (Dal Bello-Haas et al., 2012). Adults at and over age 60 years were recruited from long-term care homes across the city of Saskatoon to participate in the study.

In order to be included in the study, subjects had to have been able to follow simple instructions, been able to walk for at least 10m with or without walking aids and been available from Monday-Friday to participate in a 5-day intervention program over a 4 month period. The exclusion criteria included those who had experienced a cardiovascular event in the past 6 months, had mobility limiting arthritis, had cardiac instability, had mobility limiting vestibular disorder, had uncontrolled hypertension, had uncontrolled epilepsy, had a bone fracture in the past 4 months, were unable to comply with the study protocol, had an admission to acute care in the past 4 months, were scheduled for surgery in the next 6 months and were participating in another exercise program to improve balance and strength. (Dal Bello-Haas et al., 2012). Study timeline is illustrated in Figure 3.1.

Participants were randomized into three groups: 1) the Usual Care Group (Control group) in which participants received usual care administered by their long-term care facilities; 2) the Interpersonal Interaction Group (Social group) in which participants engaged in one-to-one interaction time with research assistants and the 3) Walking Program Group (Walking group) in which participants participated in an individualized and supervised walking program with

research assistants for half hour daily, five days per week. Prior to study commencement, 1000 IU vitamin D was prescribed to control for potential confounders and to be consistent with current health recommendations if subjects were not already supplemented.

Standardized assessments by trained research assistants were collected at baseline, weeks 8 and 16 of the intervention period and 8 and 16 weeks post-intervention, with additional data collected from patients' charts and medication administration records. Data were entered into a secure Microsoft Access database and hardcopies of the assessments scanned for future quality control. Data available at the time of this analysis (the study was ongoing at that time) were de-identified by research staffs and provided for analysis.

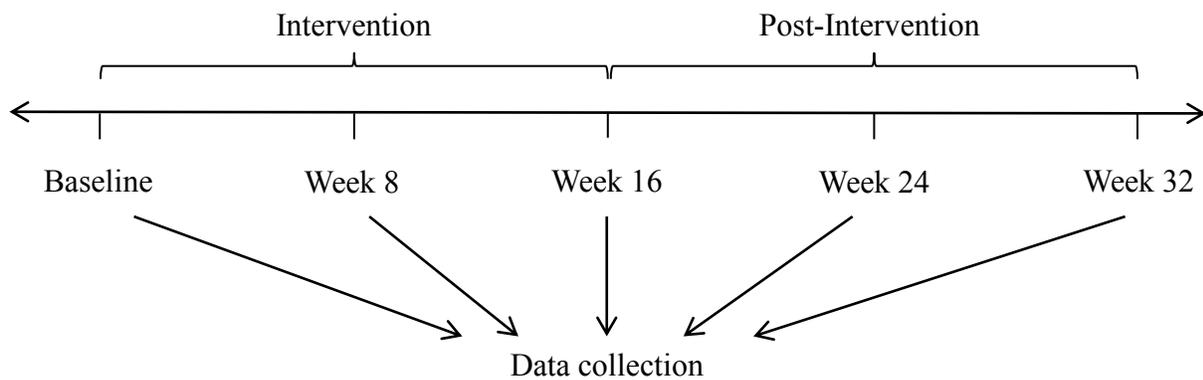


Figure 3.1 Study Timeline

Only data from baseline through week 16 were used for analysis in the current study.

3.2 Study Outcomes

3.2.1 Hand Grip Strength

A Jamar hand-held dynamometer was used to measure hand grip strength. It has been validated against functionality tests (Abizanda, Navarro, Garcia-Tomas, Lopez-Jimenez, Martinez-Sanchez & Paterna, 2012; Blankevoort et al., 2013) with high test-retest reliability of use in patients with dementia (Alencar et al., 2012). The grip handle was adjusted according to each participant's hand size. Three repetitions were performed on each hand with 30 seconds rest in between trials. The dominant hand was tested 3 times before switching to the non-dominant side. Instructions and demonstrations were given by the research assistant prior to the assessment. Subjects were seated with the upper arm positioned alongside the body and the elbow bent at 90°. The dynamometer was held in vertical position during the test. The subjects were instructed to squeeze the handle of the dynamometer as hard as possible for 3 seconds. Each score was recorded in kilograms. The maximum hand grip strength, regardless of dominance, was used for analyses.

3.2.2 Activity of Daily Living

The Older American Resource Services (OARS) Multidimensional Functional Assessment Questionnaire is a tool to assess functional status and service use in older adults. The scales of OARS (social, economic, mental health, physical health and self-care capacity) had been validated and their reliability tested in community-dwelling older adults (Fillenbaum, 1988; McDowell, 2006). The ADL scale is part of the physical health scale. There was good agreement between the ADL scale and professional-based evaluation of functional impairment severity with correlation of 0.70 (McDowell, 2006). Among users of the scales, significant inter-rater reliability was achieved with ICC ranging from 0.66-0.87 (Fillenbaum & Smyer, 1981). Five

weeks test-retest correlations among older adults were 0.82 for the basic ADL and 0.71 for instrumental ADL (McDowell, 2006). Although it is generally recommended to use the scale as a whole, the entire assessment requires approximately 45 minutes for trained individuals to complete (McDowell, 2006) and thus was too lengthy to use in this study.

The Activities of Daily Living Scale of the OARS was used to clinically assess functional status in the current study. The assessment was performed by trained research assistants. It includes instrumental and basic ADL. Only the seven basic ADL items were included in the present study because the instrumental items were not applicable in the long-term care setting. The basic ADL items include: eating, dressing/undressing, grooming, walking, bathing, continence and getting in and out of bed. A score of zero was assigned for items in which subjects were “unable to complete”. A score of one was assigned for items “completed with some help” and a score of two was assigned for tasks “completed without help”. The scores of the seven ADL items were summed to produce the total ADL scores. Individuals with higher OARS score were more independent.

Individual ADL items – the ability to eat and the ability to dress and undress – were specifically examined at baseline. The subjects in the categories of “unable to complete” and “completed with some help” were pooled together for analyses in both males and females due to small number of subjects in the “unable to complete” category.

3.2.3 Depression Score

The Cornell Scale for Depression in Dementia (CSDD) was used to assess depression in the current study. The CSDD is an assessment tool that uses information from interviews with caregivers as well as with patients directly to assess depression syndromes. It consists of 19

items that can be rated based on observations. The severity of each symptom is graded as absent, mild/intermittent, or severe. Responses from caregivers are based on observations of the patients during the week prior to the interview and patient interviews are based on inquiry and observation of the assessor at the time of assessment. If there is large discrepancy between the two responses, the caregiver is interviewed again for clarification. The final score is determined by the assessor using all available sources of information. The total time of administration and rating is approximately 30 minutes (Alexopoulos, Abrams, Young & Shamoian, 1988).

The CSDD has been validated in comparison to other depression assessment tools by Alexopoulos et al. (1988) with correlation coefficients ranging from 0.72 to 0.83 and with clinical diagnosis by Williams & Marsh (2009) with area under the curve of 0.82. It has an inter-rater reliability with weighted kappa of 0.63 for patients that were severely demented compared to 0.62 for patients with less dementia (Alexopoulos et al., 1988). Among residents in nursing homes, the CSDD was able to distinguish all categories of depression (no depression, episodic minor depression, probable major depression, definite major depression, probable major depression, definite major depression and definite major depression) with $p < 0.05$ except between residents with no depression and with minor depression (Alexopoulos et al., 1988). Sensitivity ranged from 0.75-0.83 and specificity ranged from 0.73-0.82 with Cornell score cut-off between 6 and 8 points compared against clinician's diagnosis (Williams & Marsh, 2009). Differences between caregivers and resident responses were not significantly different (Wongpakaran, Wongpakaran & van Reekum, 2013). However, there were significant differences in responses for subscales of mood-related signs, cyclic functions and ideational disturbance. Intra-class correlation coefficient of all the items ranged from 0.3-0.6, reflecting fair to moderate agreements between caregivers and residents. Stronger response agreement was found in the

cognitively impaired group (ICC=0.71) compared to cognitively intact group with ICC=0.32. Thus, the CSDD reflects a moderate agreement between caregivers and residents and best used in patients with more cognitive impairment (Wongpakaran et al., 2013).

In this study, the CSDD was administered by research assistants through interviews with caregivers and with the residents according to standard protocol (Alexopoulos et al., 1988). It covered five major areas, including: mood-related signs, behavioral disturbances, physical signs, cyclic functions and ideational disturbances. A score of zero was given when depression signs and symptoms were absent. A score of one indicated mild or intermittent occurrence and a score of two indicated severe occurrence of signs and symptoms. Scores were summed to produce a final Cornell score for analysis. Higher Cornell scores indicate more depressed individuals.

3.2.4 Cognition Score

Cognitive score was assessed using the Short Portable Mental Status Questionnaire (SPMSQ score) in the current study. The SPMSQ is based on 10 questions covering areas related to patients' orientation, memory functions related to self-care capacity, remote memory and capacity to perform serial mental operations. Subjects score a point for each incorrect response or refusal to answer. Four distinct levels of intellectual function were defined: 1) normal with capability of self-care; 2) mild with ability to handle self-care with assistance for complex matters; 3) moderate with regular assistance for complex matters and 4) severe requiring continuous supervision of activities (Pfeiffer, 1975).

The use of the SPMSQ has been validated in older adults in institutionalized settings with high distribution of scores in the moderate cognition impairment category. Among institutional settings, there was a rise in the "no response" category because residents were too deteriorated to

understand the questionnaire (Pfeiffer, 1975). While SPMSQ scores were compared against clinical diagnosis of organic brain syndrome (OBS), there were 82%-92% agreements. Test-retest correlations ranged from 0.82-0.83. It has been shown to have good precision in discriminating extreme levels of cognitive function, with 88% of subjects diagnosed with OBS in the severe category and 78% without OBS in the normal category. Mild and moderate categories had 64% and 70% of non-OBS diagnoses, respectively (Pfeiffer, 1975). Therefore, there was a strong association of SPMSQ score and OBS diagnosis. Furthermore, SPMSQ was shown to have a consistent correlation with other neuropsychological measures ranging from 0.49-0.66 (Wolber & Romaniuk, 1984).

The SPMSQ was used in the study according to standard protocol (Pfeiffer, 1975). Individuals who had higher SPMSQ scores were more demented. Normal cognition was defined as having 0-2 incorrect responses, 3-4 errors indicated mild cognitive impairment, 5-7 errors were considered moderate cognitive impairment and 8 or more errors indicated severe cognitive impairment.

3.2.5 Vitamin D Intake Status

All participants were prescribed 1000 IU of vitamin D per day at commencement of the study. The dose of vitamin D supplement before study commencement was recorded from medical records. The status of vitamin D intake (yes or no) was recorded for baseline analyses of the study.

3.2.6 Other Variables

In order to control for confounding variables, age and sex were used in the analysis. The effect of time was accounted by the days since study baseline (0, 56 and 112 days) variable.

Since the current analysis was used to explore hand grip strength, the groups participants were allocated to were treated as covariates in the data analyses.

3.3 Statistical Analysis

Data from baseline, weeks 8 and 16 of the intervention were included in the analyses. Data were analyzed using IBM SPSS v21. All statistical analyses were done separately for men and women since HGS results were significantly interactions between males and females in almost all initial data explorations. Descriptive statistics at baseline, weeks 8 and 16 were performed for all study outcomes. At baseline, linear regressions were performed on ADL scores and HGS. The independent variables for baseline ADL scores include age, HGS, SPMSQ score, Cornell score and their two-way interactions at baseline. Independent variables for baseline HGS include age, vitamin D intake, SPMSQ score, Cornell score and their two-way interactions at baseline. Binary logistic regression on individual ADL items – abilities to eat and dress/undress – at baseline were also performed. Independent variables included age, HGS, SPMSQ score, Cornell score and their two-way interactions. Insignificant predictors were sequentially removed in order of importance until a model with just significant predictors remained. Predicted values of the dependent variables were generated in cases with significant variables and interactions plotted with error bars at 95% confidence intervals (CI).

Data from baseline through weeks 8 and 16 were analyzed using repeated measure approach with the Generalized Estimating Equation function in SPSS. The Generalized Estimating Equation function would account for the different numbers of repeated measures over time for each study outcome. An autoregressive correlation matrix was used to assume same interval between subsequent observations. Repeated measure analyses were performed for ADL scores and HGS over time. The independent variables for ADL score over time include age,

baseline HGS, baseline ADL score, days since baseline and intervention groups. Independent variables for HGS include age, baseline HGS, days since baseline and intervention groups. Interactions of age and days since baseline with other variables were included to examine for plausible interactions of the variables. The schematic of the analyses is summarized in Table 3.1. Insignificant predictors were sequentially removed until a model with just significant predictors remained.

Table 3.1 Summary of Analyses at Baseline and Over Time

Independent variables	Dependent Variables			
	Baseline		Follow-ups	
	ADL[†]	HGS	ADL	HGS
Age	√	√	√	√
Vitamin D intake		√		
Cornell score	√	√		
SPMSQ score	√	√		
Baseline ADL score			√	
Baseline hand grip strength	√		√	√
Intervention groups			√	√
Days since baseline			√	√

Abbreviation: HGS: Hand Grip Strength; SPMSQ: Short Portable Mental Status Questionnaire; ADL: Activity of Daily Living

Linear logistic regression was used for baseline and generalized estimating equation for follow ups.

[†]Includes analyses of abilities to eat and to dress/undress with binary logistic regression

CHAPTER 4 RESULTS

4.1 Descriptive Statistics

A total of 161 long-term care residents had consented to participation in the study at the time of data analysis for this thesis research. Twelve of these participants withdrew and two were deceased before the active intervention component of the study, one failed screening and fifteen failed more detailed baseline assessment and were excluded from the study. Two participants had been recently enrolled but had no data available yet. Thus, a total of 129 participants were included at baseline. Tables 4.1 and 4.2 show the descriptive statistics of age and the study outcomes at baseline, weeks 8 and 16, for male and female subjects, respectively. Throughout the study, 12 participants died and 15 withdrew after study commencement.

At baseline, 32.5% of males were not supplemented with vitamin D supplement prior to study commencement. In addition, 71.8% and 15.4% of them could eat and dress/undress without help, respectively. Furthermore, 28.2% of the men were able to eat independently with some help and 69.2% of them could dress/undress with assistance. No men were unable to eat and 15.4% were unable to dress/undress themselves. Prior to study commencement, 23.6% of females did not take vitamin D supplement. In terms of abilities to eat and to dress/undress, 1.1% and 14.8%, respectively, of them were completely unable to perform the tasks. In terms of ability to eat, 29.5% of females could eat with some help and 69.3% could eat without any help. Finally, 59.1% could dress/undress with some help while 26.1% could perform the task without help. There was no difference in abilities to eat and dress/undress among males and females. Results are summarized in Tables 4.3 and 4.4. Percentages of study group assignments are presented in Table 4.5.

Table 4.1 Descriptive Statistics of Study Variables for Males

Variables	Baseline		Week 8		Week 16	
	<i>N</i>	<i>Mean ± SD</i>	<i>N</i>	<i>Mean ± SD</i>	<i>N</i>	<i>Mean ± SD</i>
Age (years)	40	84.4±7.7	-	-	-	-
Max. HGS (kgs) [†]	39	25.1±8.9	26	24.9±9.6	29	23.2±10.3
ADL score	39	8.8±2.2	30	8.2±2.4	30	7.6±2.8
SPMSQ score	39	5.6±2.8	30	5.6±2.9	30	5.9±2.8
Cornell score	39	4.1±3.6	30	4.4±5.1	29	4.1±3.6

Abbreviations: SD: Standard Deviation; HGS: Hand Grip Strength; ADL: Activity of Daily Living; SPMSQ: Short Portable Mental Status Questionnaire

[†] Significantly different from female at all time points (P<0.01)

Table 4.2 Descriptive Statistics of Study Variables for Females

Variables	Baseline		Week 8		Week 16	
	<i>N</i>	<i>Mean ± SD</i>	<i>N</i>	<i>Mean ± SD</i>	<i>N</i>	<i>Mean ± SD</i>
Age (years)	89	85.6±7.6	-	-	-	-
Max. HGS (kgs) [†]	89	15.6±6.5	71	15.4±5.7	68	13.8±6.0
ADL score	88	8.8±2.4	73	9.1±2.6	70	7.8±2.3
SPMSQ score	88	6.4±2.5	72	6.4±2.6	70	6.3±2.6
Cornell score	88	3.2±3.2	73	3.4±3.1	70	3.9±3.1

Abbreviations: SD: Standard Deviation; HGS: Hand Grip Strength; ADL: Activity of Daily Living; SPMSQ: Short Portable Mental Status Questionnaire

[†] Significantly different from male at all time points (P<0.01)

Table 4.3 Percentages of Vitamin D Intake Prior to Study Commencement

	No supplement	Supplemented
Male (%)	32.5	67.5
Female (%)	23.6	76.4

Table 4.4 Percentages of Abilities to Eat and to Dress/Undress at Baseline

	Completely Unable	Completed with Help	Completed without Help
<u>Eating</u>			
Male (%)	0	28.2	71.8
Female (%)	1.1	29.5	69.3
<u>Dressing/Undressing</u>			
Male (%)	15.4	69.2	15.4
Female (%)	14.8	59.1	26.1

Table 4.5 Percentages of Participants in Study Intervention Groups

	Control Group	Social Group	Walking Group
Male (%)	27.5	42.5	30.0
Female (%)	34.8	30.3	34.8

4.2 Baseline Analyses

4.2.1 Baseline ADL Score and ADL Items

At baseline, hand grip strength was not associated with ADL score in males (unstandardized coefficient $B=0.052$, $P=0.196$). In females, hand grip strength was a significant predictor of ADL at baseline with $B=0.079$ ($P=0.044$). Figure 4.1 shows the predicted value of baseline ADL score associated with baseline HGS in female.

Regarding individual ADL items of ability to eat and dress/undress, individuals from the “unable to complete” and “completed with some help” categories were pooled for analysis. HGS was not significantly associated with baseline ability to dress/undress in either males or females. The interaction of HGS and SPMSQ cognition score in females was significant to the outcome measure “ability to eat” with odds ratio $OR=0.946$ (95% CI: 0.903-0.992). To illustrate the association, HGS values were grouped into ≥ 15 kg and < 15 kg with SPMSQ scores, which were grouped into normal & mild (score 0-4) and moderate & severe (score 5-10), were plotted in Figure 4.2. Female residents with grip strength ≥ 15 kg had significantly higher probability of self-feeding compared to residents with grip strength < 15 kg within the same cognition status groups. Among those with stronger grip strength, females with normal or mild cognitive impairment were more likely to self-feed than those with moderate to severe impairment.

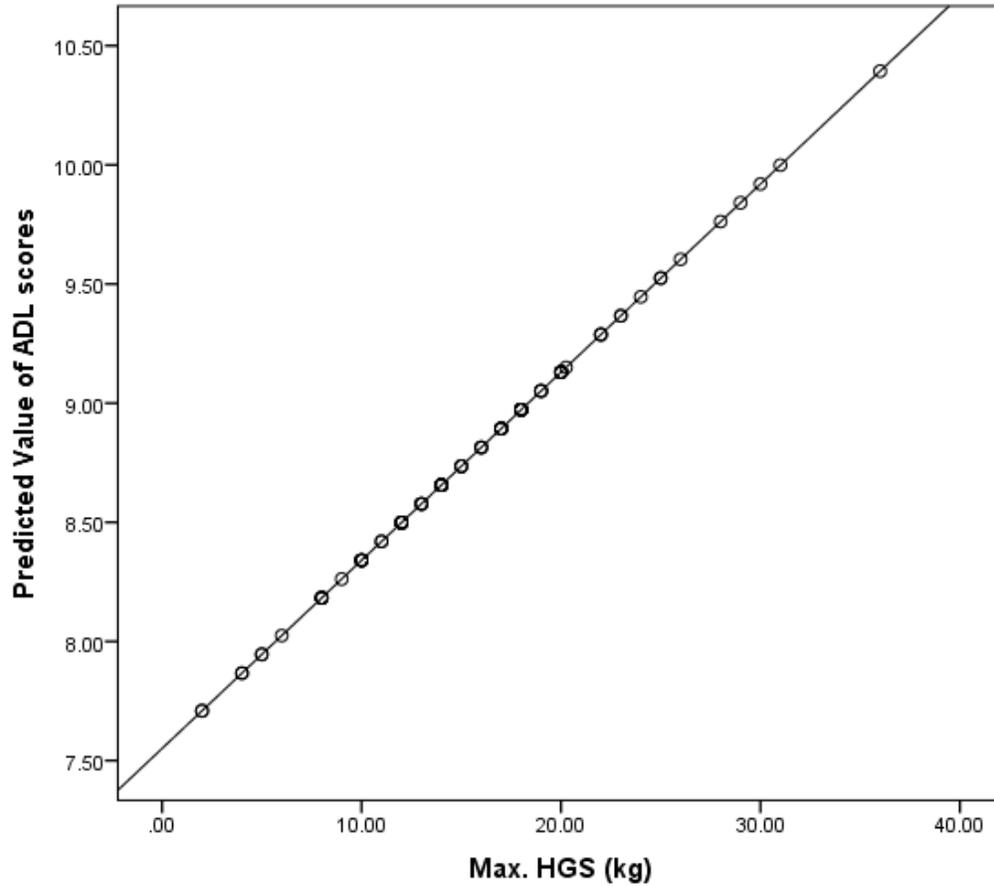


Figure 4.1 Predicted Values of ADL Scores vs HGS at Baseline in Females

Abbreviation: ADL: Activity of Daily Living; HGS: Hand Grip Strength

At baseline, HGS was significantly associated with ADL in females with coefficient $B=0.079$, $P=0.044$.

Graph shows predicted value of ADL score based on model vs max.

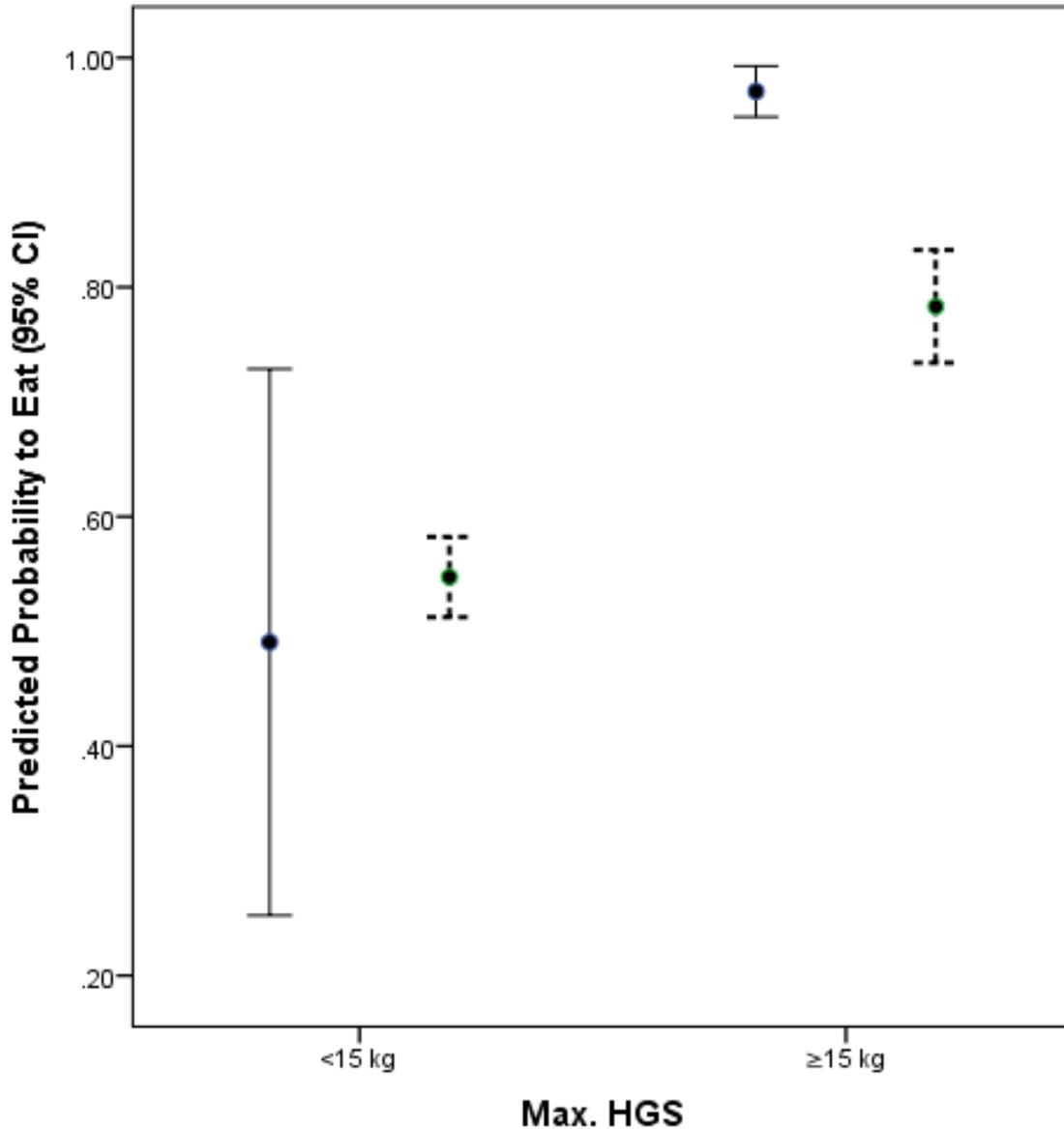


Figure 4.2 Probability to Eat Associated with HGS and SPMSQ Scores at Baseline in Females.

Abbreviation: HGS: Hand Grip Strength; CI: Confidence Intervals

Females were grouped based on baseline mean HGS ≥ 15 kg and <15 kg and SPMSQ scores were grouped into normal and mild (score 0-4; solid error bars) and moderate and severe (score 5-10; dotted error bars). At baseline, ability to eat was associated with HGS and SPMSQ score interaction in females (OR=0.946; 95% CI=0.903-0.992). Female residents with higher grip strength had higher probability of self-feeding within the same cognition status group. Considering only females from the ≥ 15 kg strength group, poorer cognitive status seemed to attenuate the probability of eating.

4.2.2 Baseline HGS

Age was the only significant factor significantly associated with HGS in males at baseline (B= -0.572, P=0.001) (Figure 4.3). Older men had significantly lower HGS compared to younger men. No variables were found to be significantly associated with HGS at baseline in females. Summary of baseline predictors of ADL score and HGS with regression coefficients is presented in Table 4.6.

Table 4.6 Baseline Predictors of ADL Score and HGS in Males and Females

	Male			Female		
	Predictors	β	P-value	Predictors	β	P-value
ADL score	- [†]	-	-	HGS	0.215	0.044
HGS	Age	-0.496	0.001	- [‡]	-	-

Abbreviations: ADL: Activity of Daily Living; HGS: Hand Grip Strength; β : standardized coefficient

[†]No significant predictors were present for baseline ADL score in males; HGS was not a significant predictor

[‡]No significant predictors were present for baseline HGS in females

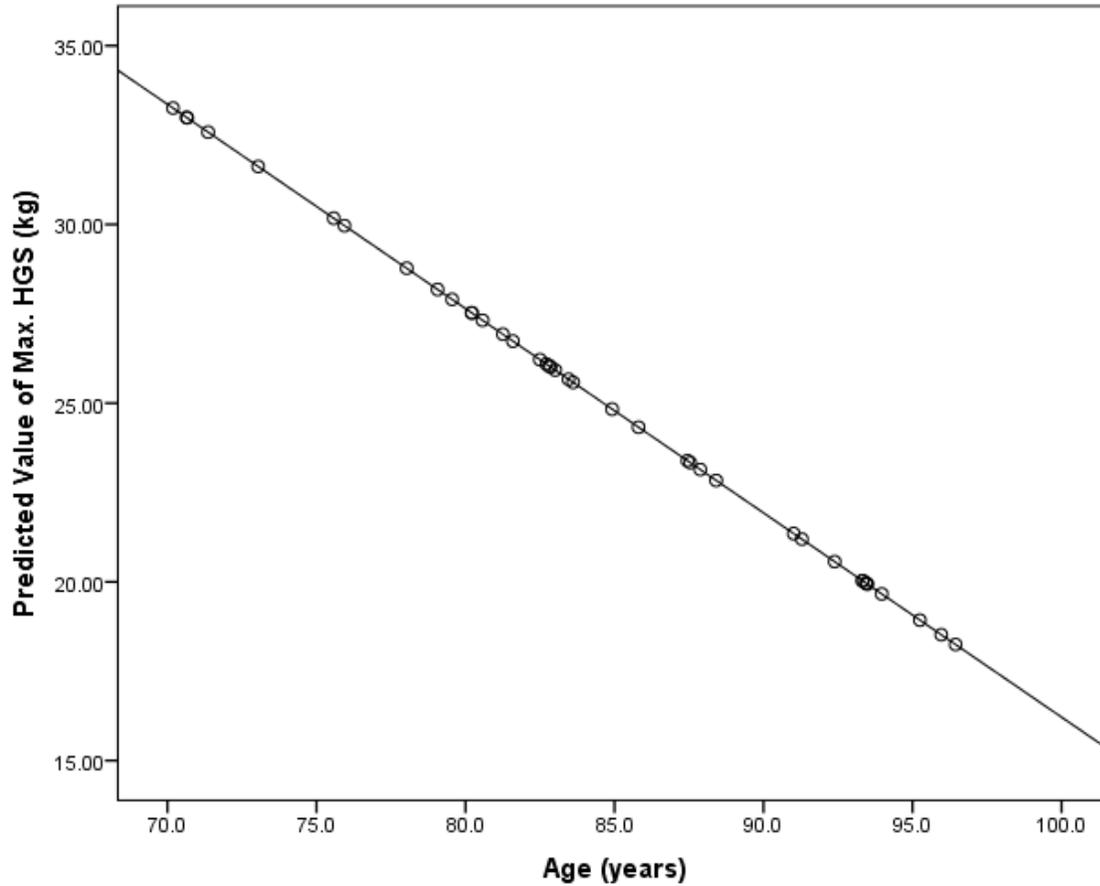


Figure 4.3 Predicted Values of HGS vs Age at Baseline in Males.

Abbreviation: HGS: Hand Grip Strength

At baseline, age was significantly associated with HGS in males with coefficient $B=-0.572$, $P=0.001$.

Graph shows predicted value of max. HGS based on model over age (years).

4.3 Longitudinal Analyses

4.3.1 Longitudinal ADL Scores

From the longitudinal analysis of data from baseline through week 16, independent predictors of ADL scores over time in males included days since baseline ($P<0.01$) and baseline ADL ($P<0.01$). More independence of ADL at baseline was associated with better ADL in the future. However, baseline HGS ($P=0.157$) was not a significant predictor of future ADL. The regression model is presented in Table 4.7. In order to illustrate the association, baseline ADL with cut-off scores above and below 9 points were used to plot error bars over time for ADL. Figure 4.4 illustrates the trend of ADL scores over days since baseline.

In females, the interaction between age and baseline HGS was a significant predictor of future ADL ($B=-0.006$, $P=0.028$). However, the interactions between days since baseline with age ($B=-0.001$, $P=0.002$) and days since baseline with baseline ADL ($B=-0.006$, $P<0.01$) and study groups with age ($B=0.090$, $P=0.052$ for Social group; $B=0.099$, $P=0.030$ for Walking group) were also significant predictors. Figure 4.5 and 4.6 illustrate these interactions.

Table 4.7 Regression Model for ADL Score over the Intervention Period for Males

Parameter	B	SE	95% Wald CI	P-value
(Intercept)	1.019	0.6934	(-0.340, 2.378)	0.142
Days since Baseline	-0.013	0.0034	(-0.020, -0.007)	<0.01
Baseline ADL	0.805	0.0714	(0.665, 0.945)	<0.01
Baseline HGS	0.026	0.0185	(-0.010, 0.062)	0.157
(Scale)	2.763			

Abbreviations: B: Unstandardized coefficient; SE: Standard Error; CI: Confidence Interval
Days since baseline and baseline ADL were significant predictors of ADL over time ($P<0.01$)

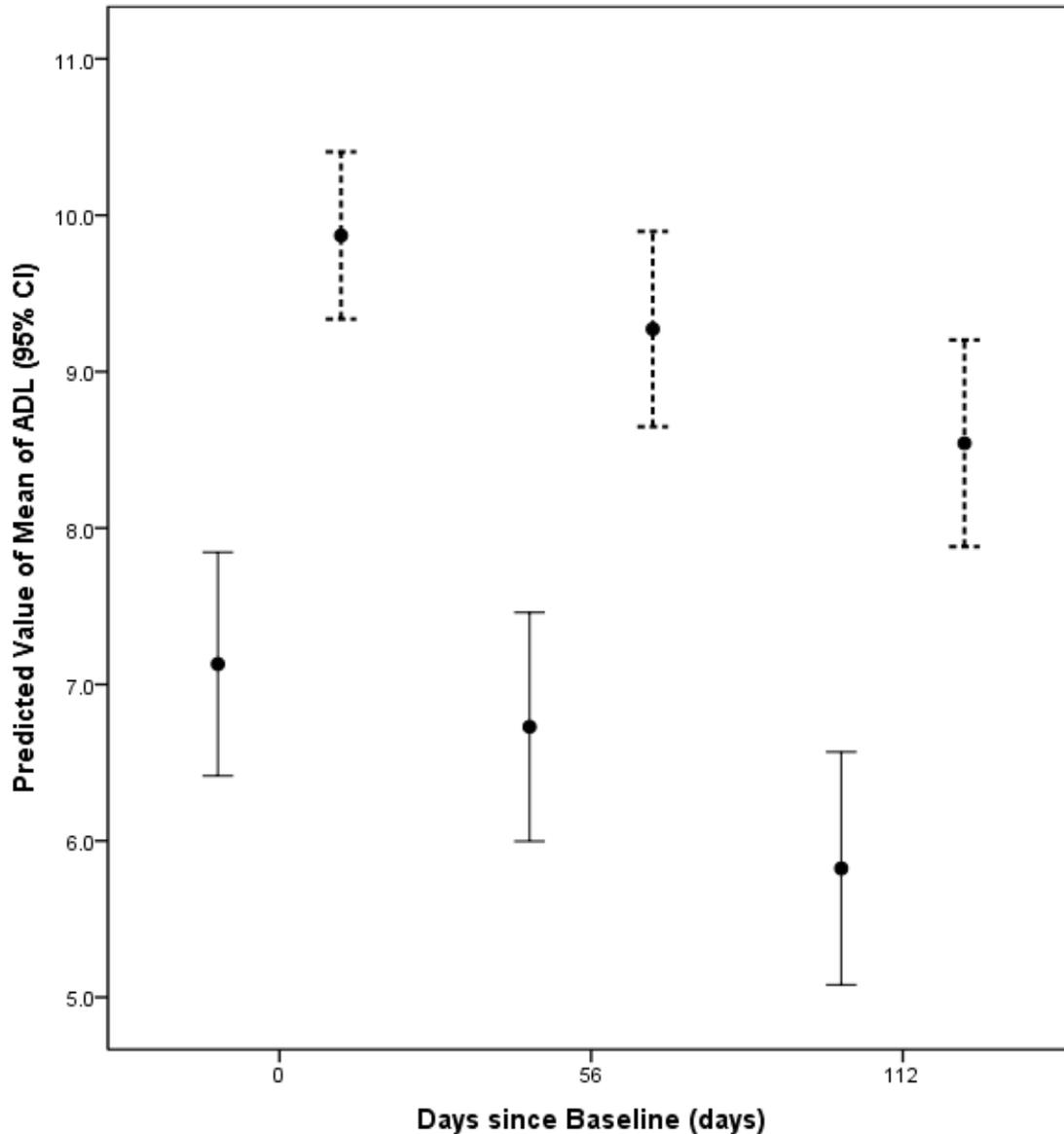


Figure 4.4 Predicted Mean of ADL with Baseline ADL in Males.

Abbreviation: ADL: Activity of Daily Living; CI: Confidence Intervals

Baseline ADL score was grouped into <9 points (solid error bars) and ≥9 points (dotted error bars). Days since baseline and baseline ADL were significant predictors of subsequent ADL. ADL independence worsened over time regardless of baseline ADL and males with worse ADL at baseline had significantly lower ADL than those with better baseline ADL.

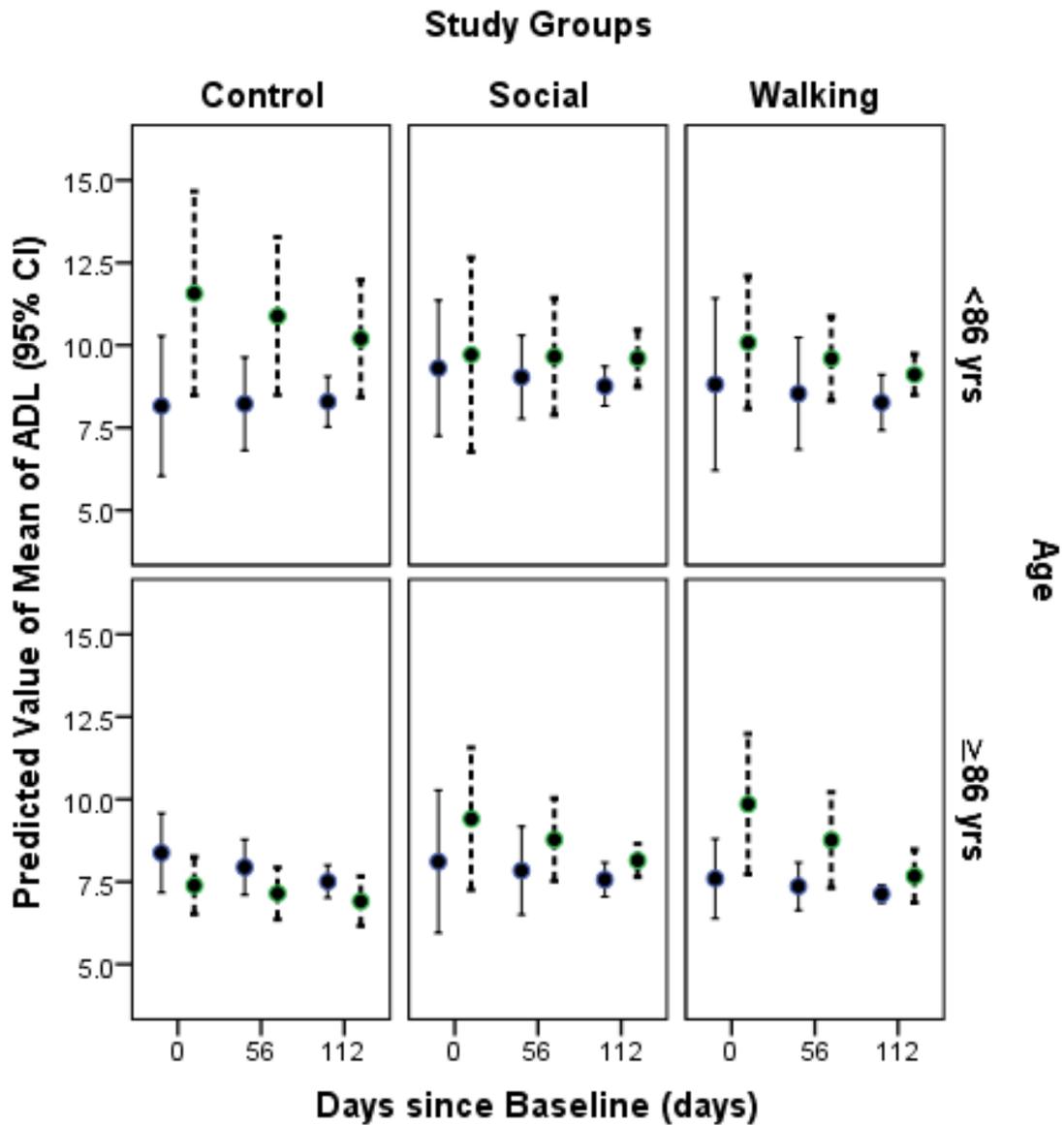


Figure 4.5 Predicted Mean of ADL Scores over Time with Study Groups, Age and Baseline HGS in Females.

Abbreviation: ADL: Activity of Daily Living; CI: Confidence Intervals

Baseline max. HGS were grouped into <16 kg (solid error bars) and ≥16 kg (dotted error bars). Predicted means of ADL over time with age, study groups and baseline HGS in females. Older and weaker females tend to have more dependence of ADL.

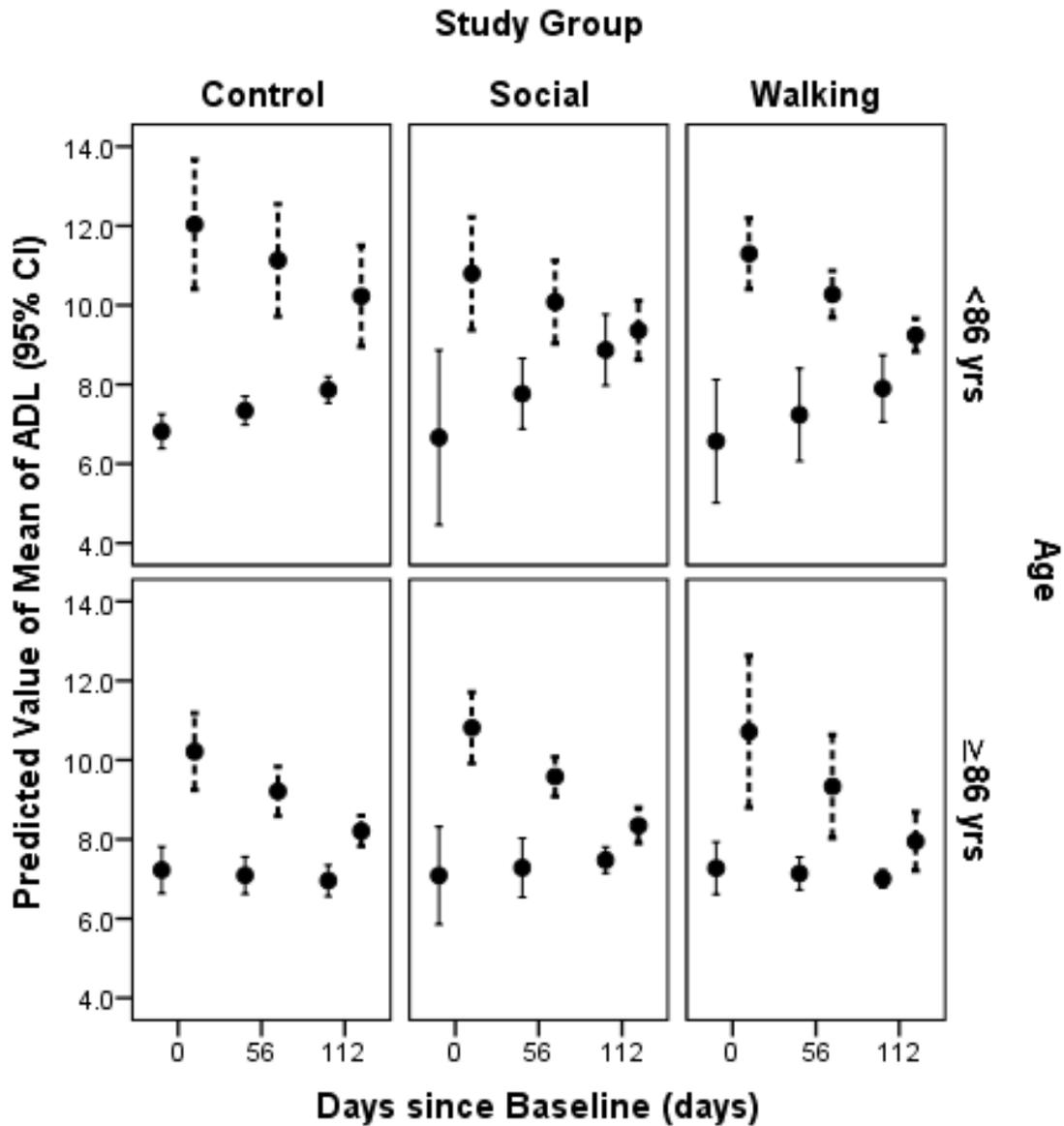


Figure 4.6 Predicted Mean of ADL Scores over Time with Study Groups, Age and Baseline ADL in Females.

Abbreviation: ADL: Activity of Daily Living; CI: Confidence Intervals

Baseline ADL score was grouped into <9 points (solid error bars) and ≥9 points (dotted error bars). The interaction of Days since Baseline with Baseline ADL was a significant predictor of subsequent ADL. Females with higher baseline ADL performed better than those with worse ADL at baseline. ADL independence worsened over time among females with higher baseline ADL, but not the ones with poorer ADL. Younger women with poorer baseline ADL seemed to respond better to study interventions over time.

4.3.2 Longitudinal HGS Analysis

Days since baseline ($B=-0.024$, $P=0.001$) and baseline HGS ($B=1.004$, $P<0.01$) in males were independent predictors of HGS over time. The interaction between study groups and age were also significant as shown in Table 4.8 and illustrated in Figure 4.7. In females, the interactions of days since baseline with baseline HGS ($B=-0.002$, $P<0.01$) and study groups with age ($B=0.283$, $P<0.01$ for Social group and $B=0.172$, $P=0.005$ for Walking group) were significant predictors of subsequent HGS as shown in Table 4.9. The interactions are illustrated in Figure 4.8.

Table 4.8 Regression Model for HGS over the Intervention Period for Males

Parameter	B	SE	95% Wald CI	P-value
(Intercept)	0.168	3.7996	(-7.279, 7.615)	0.965
Days since Baseline	-0.024	0.0070	(-0.037, -0.010)	0.001
Baseline HGS	1.004	0.0297	(0.945, 1.062)	<0.01
Walking group \times age [†]	-0.125	0.0493	(-0.222, -0.029)	0.011
Social group \times age [†]	0.172	0.0763	(0.022, 0.321)	0.024
(Scale)	11.717			

Abbreviations: B: Unstandardized coefficient; SE: Standard Error; CI: Confidence Interval

[†]Compared to control group \times age as reference

Days since baseline, baseline HGS and study groups with age interactions were significant predictors of HGS over time (P<0.05)

Table 4.9 Regression Model for HGS over the Intervention Period for Females

Parameter	B	S.E.	95% Wald CI	P-value
(Intercept)	15.912	4.3581	(7.371, 24.454)	<0.01
Days since Baseline \times Baseline HGS	-0.002	0.0007	(-0.004, -0.001)	<0.01
Walking group \times age [†]	0.172	0.0616	(0.051, 0.292)	0.005
Social group \times age [†]	0.283	0.0566	(0.0566, 0.172)	<0.01
(Scale)	6.930			

Abbreviations: B: Unstandardized coefficient; S.E.: Standard Error; CI: Confidence Interval

[†]Compared to control group \times age as reference

Interactions of days since baseline with baseline HGS and study groups with age were significant predictors of HGS over time (P<0.01)

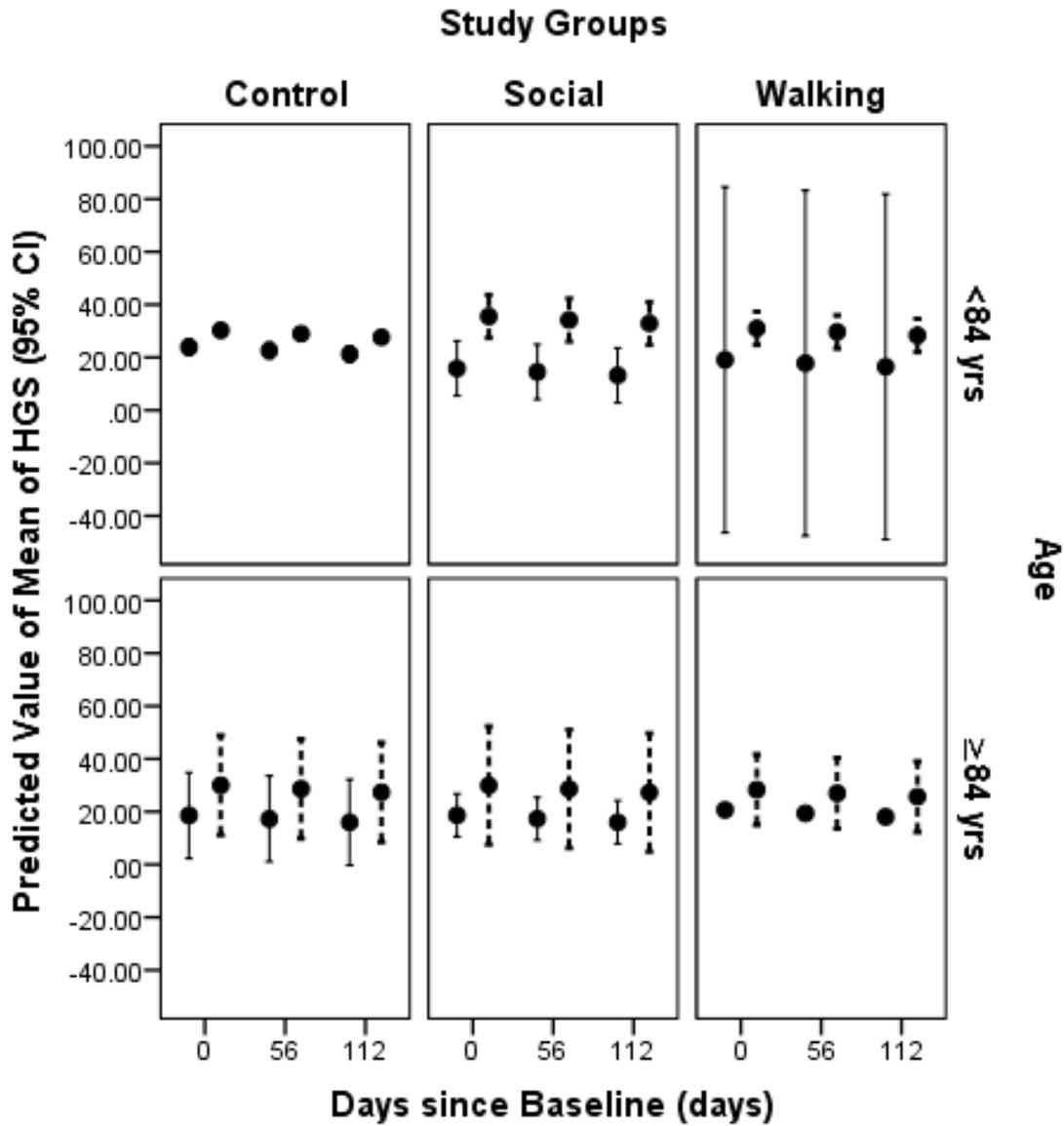


Figure 4.7 Predicted Mean of HGS over Time with Study Groups, Age and Baseline HGS in Males.

Abbreviation: HGS: Hand Grip Strength; CI: Confidence Intervals

Baseline max. HGS was grouped into <25 kg (solid error bars) and ≥25 kg (dotted error bars). Baseline HGS and days since baseline were independent predictors of subsequent HGS. The interaction of study groups and age is shown.

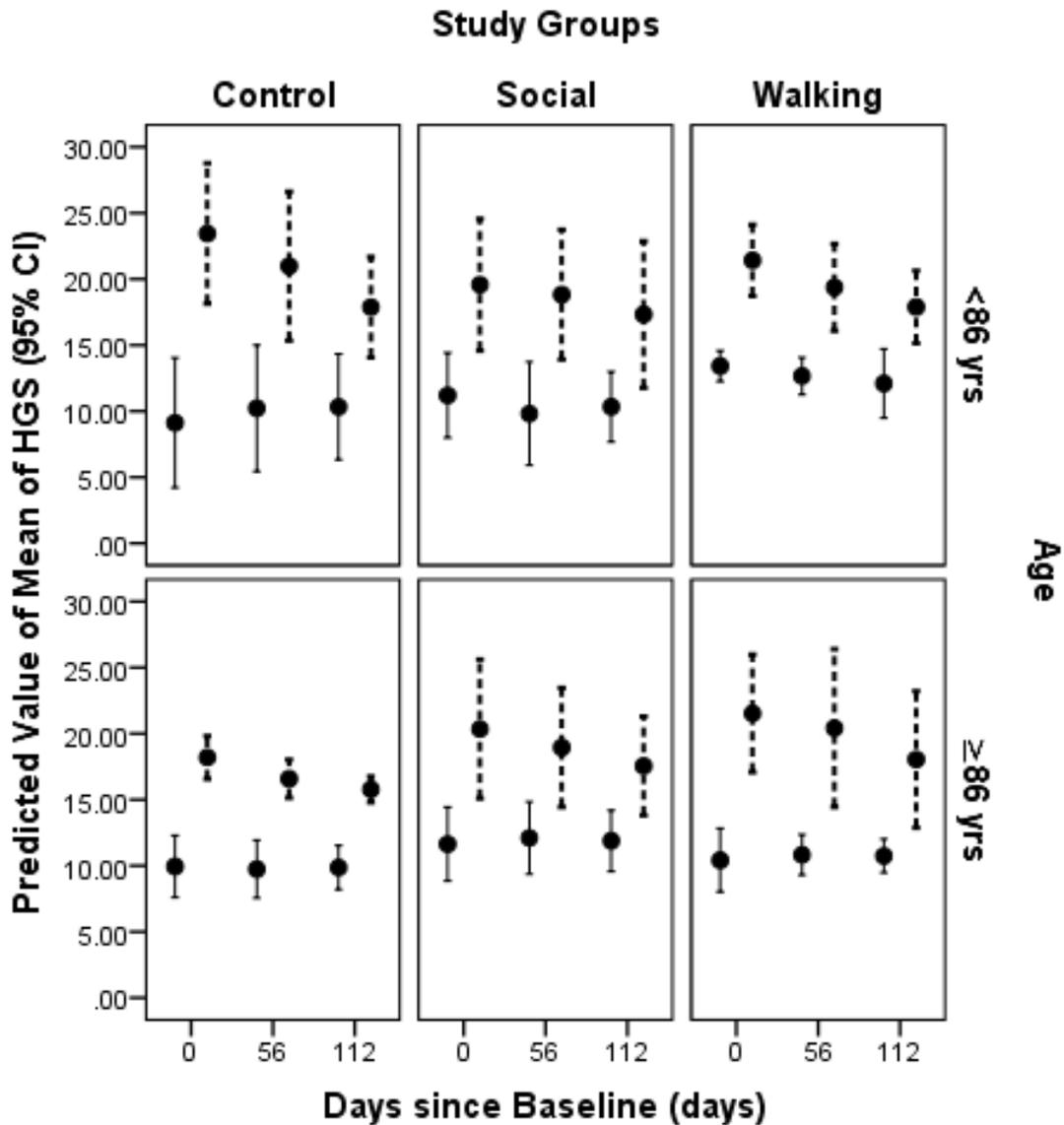


Figure 4.8 Predicted Mean of HGS over Time with Study Groups, Age and Baseline HGS in Females.

Abbreviation: HGS: Hand Grip Strength; CI: Confidence Intervals

Baseline max. HGS was grouped into <16kg (solid error bars) and ≥16 kg (dotted error bars). The interactions of study groups with age and days since baseline and baseline HGS are shown.

CHAPTER 5 DISCUSSION

5.1 Baseline HGS Association (Cross-sectional analysis)

In this study, grip strength was significantly different between males and females over all time points. The mean maximum HGS for men was 25 kg and 16 kg for women at baseline. Results were comparable to normative values in healthy unimpaired older adults in the age groups of 80-84 years for men and 85-89 years for women (Bohannon et al., 2007) and definitive HGS cut-off values of 26 kg and 16 kg, respectively, for sarcopenia (Alley et al., 2014). Thus, the mean HGS values from the current study was used for analyses. Values were lower than the cut-offs of 30 kg and 20 kg for men and women suggested by data for clinical relevance from the InChianti study, but subjects in that study were community-dwelling individuals with higher functionality and mobility (Lauretani et al., 2003).

At baseline, higher grip strength was associated with more independence of ADL in females only, but not in males. This latter finding was contrary to findings in community-dwelling older men where hand grip strength was significantly associated with ADL (Hairi, Cumming, Naganathan, Handelsman, Le Couteur, Creasey et al., 2010). Another study which included both community-dwelling older adults and institutionalized individuals also found an association between HGS and ADL in both men and women, but the proportion of long-term care residents was only 14% compared to 58% of community-dwelling and 28% sheltered subjects (Taekema et al., 2010).

The association of HGS with ADL in females but not in males may be explained by the higher incidence density for ADL disability over six years. Community-dwelling women had significantly higher incidence (42.4/1000 women/year) of developing ADL disability compared

to men (17.5/1000 men/year). In addition, among individuals above 80 years, incidence of all individual ADL items (dressing, transferring, bathing, walking, continence and eating) disability was greater among women than men. The incidence of disability in eating was 26.5/1000 women/year and 11.2/1000 men/year. Reduced hand grip strength affecting the osteoarticular system may result in disability more for women (Alexandre et al., 2012). The greater incidence of ADL disability in women, especially the disability to eat, may explain the observed association of HGS with ADL and ability to eat in females. Although in the literature, lower HGS was associated with disability in dressing, but not eating (Rantanen et al., 1999), might indicate an early onset of disability (Alexandre et al., 2012). However, such a scenario is unlikely in the present study as the residents are older with less mobility and functionality due to institutionalization and more cognitive impairment.

No association was found between ability to dress and HGS may be related to the greater body movements involved while dressing/undressing which would require assistance regardless of strength as observed from equal distribution of individuals among levels of assistance. While examining the association between HGS and ability to eat, the interaction term of HGS and cognition status by SPMSQ was a significant predictor of ADL in females. Individuals with greater HGS had higher probability of eating independently compared to those with lower HGS within the same cognition group. However, among women with stronger strength, poorer cognition attenuated the effect of HGS on the ability to eat with probability of 0.78 compared to probability of 0.97 for intact and mildly impaired cognitive status.

Age was a significant predictor of HGS in men only, but not in females. Younger men (< 84 years) had stronger grip strength than older men. Age is known to be a strong determinant of HGS in both males and females (Bohannon et al., 2007; Frederiksen et al., 2006; Massy-

Westropp et al., 2011; Schlüssel et al., 2008; Shields et al., 2010). Younger men could be more cognitively intact than older men, thus more able to perform grip strength test. It has been shown that low muscle strength coexisted with poor cognitive function (Huh et al., 2011) or might even precede cognitive impairment (Auyeung et al., 2011). The older men who performed worst on HGS were older and slightly more cognitively impaired. The observed effect of age on HGS in men may also be due to a more accelerated decline of HGS compared to women. While examining HGS over age, men had an average of -0.57 kg, compared to a -0.12 kg in women for every year of age increment at baseline. Men had greater decrease in HGS (standardized slope=-28.7) over a 6-year period than women (standardized slope=-18.6) in the age group of 76-99 years (Diehr et al., 2013). Men also experienced greater absolute decline in HGS than women over a 22-year period (Stenholm et al., 2012). From HGS values of healthy individuals, HGS in men decreased at a faster rate than women after the age of 60 years (Gunther et al., 2008; Luna-Heredia et al., 2005; Hurley, 1995). The distribution of HGS over age for men and women also differed in the current study. There was a clear gradient of decreasing HGS with age for men, but such gradient was not observed in females. The distribution of HGS in women appeared to be flat over age. This is in agreement with a leveling-off effect of HGS with age among the oldest old women (Frederiksen et al., 2006). The greater decline of HGS with age in men might allow the association to be detected at baseline.

5.2 HGS Associations over 16 Weeks (Longitudinal analysis)

In men, ADL over a 4-month period was significantly affected by time and baseline ADL. However, baseline HGS did not predict subsequent ADL. The association of time and baseline ADL with subsequent ADL was not surprising. Men with greater ADL independence at baseline remained to be more independent in the future, but independence declined gradually

over time regardless of baseline ADL. Aging as a nonmodifiable risk factor contributed significantly to ADL dependence and functional disability (Sabol et al., 2011) over time. Higher baseline ADL may shift the declining curve to the right to delay the onset of dependence until a later age.

In women, the interactions of days since baseline with age, days since baseline with baseline ADL, study groups with age and age with baseline HGS significantly predicted subsequent ADL. Females age <86 years with baseline HGS ≥ 16 kg in all study groups were more ADL independent than those with HGS <16 kg over a period of four months. Stronger strength at baseline might have attenuated ADL decline. In the Disablement Process Model, active underlying pathology could lead to muscle function impairment and further cause observable muscle strength limitation and disability (Sabol et al., 2011). Along the main disablement process, extrinsic and intrinsic risk factors could modify the outcomes of the pathway. The high prevalence of comorbidity in long-term care residents could initiate the disablement process. Lower baseline HGS observed in this study could indicate outcomes of underlying comorbidity and pathophysiology and an onset of subsequent disability of ADL.

Younger participants age <86 years seemed to respond better than their older counterparts to the study regardless of baseline HGS. Although stronger women age <86 years in the control group seemed to be more ADL independent compared to the other study groups, the effect may be due to a coincidental higher ADL score at baseline. Among women age ≥ 86 years, individuals with stronger baseline HGS had more ADL independence except those in the control group. Women ≥ 86 years in the control group performed the worst in ADL. Within this group, those with HGS ≥ 16 kg (N=7) had a mean age of 91.7 years whereas those with HGS <16kg had a mean age of 89.5 years (N=12). This was contrary to the other study groups and age-interaction

groups in which older women had weaker strength. This group of older women might exhibit other aspects of frailty other than muscle weakness that impact ADL performance.

Figure 4.6 illustrates the responses of women age <86 years with poor ADL independence to participation in the study with slight increment of ADL score over time. It was surprising to note the increase of ADL score in the social group, suggesting social interaction might have an effect on ADL of women age <86 years. A meta-analysis of physical rehabilitation of ADL, including mobility, flexibility and resistance training, in long-term care residents showed significant improvement over a median of four months period. Small increment of ADL would be meaningful in institutionalized residents because of its importance (Crocker et al., 2013). Although only a small increment of ADL was observed in the current study, it would be worthwhile to investigate the effects of social interaction on ADL. Longer study duration may allow for more observation of intervention effects. However, such response was not seen among women age ≥ 86 years, suggesting a need for early maintenance of functionality. Regardless of study groups and age, more ADL independence at baseline resulted in higher subsequent ADL independence.

For subsequent hand grip strength, baseline HGS, days since baseline and the interaction of study groups with age significantly predict subsequent HGS in males. Time had a small negative effect and baseline HGS had a strong positive effect on subsequent HGS. Results were incomparable among study groups due to small sample size and missing values for males. Stronger men at baseline retained higher subsequent strength compared to men with weaker baseline HGS although all strength groups declined gradually over time. A similar trend was observed in women and results were more significant. Stronger women significantly remained stronger than weaker women at baseline over the study period. However, HGS did not improve

over time regardless of study groups. The interventions might be insufficient to offset the decline of HGS over time. Resistance training (Cadore et al., 2014; Moreira et al., 2013) might be more appropriate for HGS improvement compared to the interventions of the current study.

5.3 Relevance to Dietetics

Hand grip strength can be used as a quick and easy to perform screening tool upon long-term care admission. Dietitians can utilize HGS measurements to screen for individuals who are at risk of frailty using the cut-off values of 25 kg for men and 16 kg for women. Dietitians need to pay attention to individuals with lower HGS and cognitive impairment as these individuals may have poorer ADL independence, especially poorer ability to self-feed, thus compromising optimal nutrition intake. Cues to poor eating behaviors should be noted early for interventions to ensure adequate intake. A standardized algorithm for detecting frailty and malnutrition should be employed. HGS measurements should be interpreted together with other nutrition assessments such as unintentional weight loss, presence of edema, diet history and biochemical markers. Nutrition status should be optimized to aim for maintenance of overall health status and prevent malnutrition.

Dietitians and long-term care staff should also pay attention to residents' social well-being as socializing might have a small effect on ADL improvement to preserve functionality. It was shown that the effect was greatest among younger residents; thus an early preventative approach should be employed. For older residents, social interactions may be beneficial in preserving functionality.

5.4 Study Limitations

This study provides information on HGS for older adults living in long-term care facilities, which to the author's knowledge, is lacking in the current literature. The values of HGS are also in agreement with current recommended threshold values for definition of sarcopenia in older adults, in which the current study sample correctly reflects as frail with limited mobility.

Although a total sample size of 129 could provide enough power for repeated measure analyses, most of the participants were female (69%) with only 40 providing baseline data for males. This might have limited the ability to detect statistically significant associations of HGS within males for repeated measures. Furthermore, the number of available outcome data decreased over time due to withdrawal and increasing inability to perform tests over time, which further limited the number of available data.

Vitamin D intake status, SPMSQ score and Cornell score were not used for analyses over the intervention period. Vitamin D intake status was only based on the medication list prior to study commencement and serum 25(OH)D level was not available for all participants. Most residents were already supplemented with vitamin D in accordance with current recommendation of 800 IU for older adults. Duration of supplementation and history of previous supplementation were also unknown. It was therefore decided that inclusion of vitamin D status at baseline in the longitudinal analyses would not be meaningful. Thus, it was only used at baseline HGS analysis to control for a potential confounding effect. The SPMSQ score for cognition status was not used because the study inclusion criteria had selected individuals who were able to follow simple instructions, which resulted in the selection of a relatively more cognitively homogeneous subgroup. Thus it was only used at baseline to examine for a cross-sectional association. Finally,

Cornell score was not used because responses regarding residents' depression status were too unreliable. For example, research staff found that discrepancies existed between caregiver interview reports even on the same day regarding the same residents. Responses of depressive symptoms based on caregivers' memories and supervision of multiple residents may have produced inaccurate descriptions of residents' depressive symptoms. However, exclusion of the SPMSQ and Cornell scores over the intervention period for analyses limited the ability to detect effects of these parameters.

Other limitations of the study were that the analyses did not examine residents' comorbidity and medical history such as reasons for admission. However, given the high prevalence of multiple morbidity and polypharmacy in such population with a relatively small sample size, statistically significant analyses would be difficult to reach. In addition, BMI was not included for analyses, but it would not be an accurate measure due to the changing body composition of older adults with the presence of edema. The intervention groups also added complications to interpreting associations of the variables. Lastly, daily activities of the residents outside the study may confound study results. Caregivers may have prioritized their attention to residents who were not in the intervention group since the research assistants were spending time with these residents.

5.5 Conclusions

In conclusion, long-term care residents had hand grip strengths in the frail category. Additional frailty assessments should be performed in cases of low grip strength at screening for comprehensive diagnosis. Caregivers and health professionals should be attentive to low HGS and cognitive impairment as indication of risk for functional disability. The predictive value of HGS on subsequent ADL is influenced by other factors such as age and time effect, thus its

values should be interpreted with caution. However, a low HGS warrants further examination of underlying pathology to prevent or delay the onset of further functional deterioration in long-term care older adults.

5.6 Future Research

This thesis work has only included parts of the data from the walking program research study. Completion of the research study and more available data are needed to understand the effects of the unique characteristics of long-term care residents on hand grip strength. Qualitative data of the research study may be useful in further explaining some of the associations and improving future exercise interventions for long-term care residents.

In this thesis work, the association of nutritional status among long-term care residents and their hand grip strength has not been examined, but it would be useful in future work to examine the association of nutritional assessments or dietary analysis with hand grip strength in long-term care older adults. Further research on hand grip strength needs to be done in relation to nutritional status of long-term care residents to confirm the threshold for screening of malnutrition. Future work can also examine the feasibility and added benefits of incorporating hand grip strength measurements into the nutrition assessment step of the Nutrition Care Process in dietetic practices.

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