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Cognitive and Psychosocial Factors Associated with Sarcopenia in Older Adults

Murad Taani
University of Wisconsin-Milwaukee

COGNITIVE AND PSYCHOSOCIAL FACTORS ASSOCIATED WITH SARCOPENIA IN OLDER ADULTS

by

Murad Taani

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ABSTRACT

COGNITIVE AND PSYCHOSOCIAL FACTORS ASSOCIATED WITH SARCOPENIA IN OLDER ADULTS

by

Murad Taani

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Under the Supervision of Dr. Christine Kovach

Objectives: To describe the muscle mass, strength, and function of older adults living in residential care apartment complexes (RCACs) and examine the association between self-efficacy for exercise, depressive symptoms, social support and sarcopenia. The convergent validity of Muscle Mechanography (MM) when compared to the traditional muscle function and strength tests was also tested.

Design: Secondary data analysis of baseline data from a clinical trial.

Setting: One RCAC in the Midwestern United States.

Participants: Thirty-one older adults living in one RCAC.

Measurement: Muscle mass was measured by bioelectrical impedance spectroscopy. Muscle function was evaluated by the Short Physical Performance Battery test, Timed Up and Go test, and MM. Grip strength was measured by a Jamar® hand dynamometer. Self-efficacy for exercise was measured by the Self-efficacy for Exercise Scale. Depressive symptoms were measured by the Geriatric Depression Scale. Social support was measured by the Lubben Social Network Scale.

Results: Participants had lower values of muscle mass, strength, and function compared to values obtained in previous research. A sex difference exists for muscle mass, strength, and

function. The findings showed a trend for individuals with high self-efficacy, without depressive symptoms, and with strong social support to present greater muscle mass, strength, and function. The findings also demonstrated convergent validity across all the examined measures of muscle function and strength.

Conclusion: This study is only one of a few to describe the muscle outcomes and evaluate the relationship between selected cognitive and psychosocial factors and sarcopenia among older adults living in RCACs. The preliminary findings of this study warrant further investigation of an intervention aimed at maintaining or improving the muscle outcomes of RCAC residents. While the interpretation of findings should be presented with caution and replicated with other samples, this study may provide a new understanding about the muscle outcomes and the relationship between self-efficacy for exercise, depressive symptoms, and social support and sarcopenia. Improved understanding of muscle outcomes and the relationship between cognitive and psychosocial factors and sarcopenia is crucial. The findings also provided a new evidence about MM as a new technology to quantitively assess muscle function in older adults, potentially making this a valuable research tool.

To

Hekmat Taani and Shama Taani

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CHAPTER 1

This chapter introduces the problem of decreased muscle mass, strength, and function in older adults living in residential care apartment complexes (RCACs). This problem is commonly referred to as sarcopenia. The terms, decreased muscle mass, strength, and function and sarcopenia will be used interchangeably in this study. In this study the term RCACs refers to facilities licensed by the state at a non-nursing home level of care, which provide room, board, 24-hour oversight, and minimal hours of assistance with activities of daily living. This study will fill gaps in the literature in three areas that are introduced in this chapter; it will a) describe the characteristics of muscle mass, strength, and function in older adults living in RCACs; b) describe the relationship of select cognitive and psychosocial factors to sarcopenia; and c) examine the convergent validity of Muscle Mechanography (MM) method with traditional muscle function tests. This chapter describes prevalence and significance as well as an introduction to the potential risk factors associated with decreased muscle mass, strength, and function among older adults. Gaps in the literature and the purpose of this study are given. The Individual and Family Self-management Theory (IFSMT) is described, conceptual definitions are provided, and the application of this theory to the study is discussed.

Introduction to the Problem

The reduction of muscle mass, strength, and function is one of the most consistent changes that occurs with aging and is considered one of the main causes of disability in older adults (Bruyère et al., 2016; Fielding et al., 2011; Morley, 2012). Recent estimates indicate that up to 45% of older adults in the United States suffer from sarcopenia (Janssen, Shepard, Katzmarzyk, & Roubenoff, 2004). Older adults with sarcopenia are at great risk for disastrous health outcomes such as premature death and disability caused by falls, fractures, head injuries, limited mobility, and impaired daily functioning (Bruyère et al., 2016; Buehring, Krueger, & Binkley, 2010; Janssen et al., 2004; Morley, 2012). Sarcopenia also leads to an increased use of nursing homes, long-term care (LTC) facilities, and hospital inpatient treatment (Janssen et al., 2004). These negative health outcomes are costly to the individual, the healthcare system, and society as a whole (Bruyère et al., 2016; Morley, 2012).

Several medical explanations for sarcopenia have been proposed related to genetic factors, endocrine issues, hormonal changes, protein synthesis, proteolysis, and inflammatory processes (Fielding et al., 2011; Henwood, Keogh, Reid, Jordan, & Senior, 2014). While many of these mechanisms and their relationship to the onset and progression of sarcopenia are well-understood, the cognitive and psychosocial risk factors for developing sarcopenia are poorly understood (Brady, Straight, & Evans, 2014; Campbell & Vallis, 2014; Henwood et al., 2014). A greater understanding of the factors contributing to sarcopenia in older adults is needed (Henwood et al., 2014). As sarcopenia is highly prevalent, identifying the treatable risk factors of sarcopenia is considered to be a crucial step to prevent decline in muscle mass, strength, and function in older adults (Fielding et al., 2011). Exploring these factors may enable the development of interventions to prevent or decrease potential consequences of sarcopenia in older adults.

Prevalence and Significance

Researchers estimated that more than 50% of older adults suffer from sarcopenia around the world (Cruz-Jentoft, Landi, Topinkova, & Michel, 2010). In the United States, researchers estimate that 45% of the elderly population is sarcopenic and 64% of adults over 65 years of age reported limitations in at least one domain of physical function including walking, climbing, standing, and sitting (Janssen et al., 2004, McAuley, Szabo, Gothe, & Olson, 2011). Morley

(2012) reported that there are 3.6 million older adults in the United States who are sarcopenic. In the New Mexico Elder Health Survey study, the prevalence of sarcopenia was determined to be over 50% in individuals older than 80 years (Baumgartner et al., 1998). In a systematic review by Cruz-Jentoft et al. (2014), the prevalence of sarcopenia in older adults was 1–33% across multiple populations and communities. Cruz-Jentoft et al. (2014) reported that the rates of sarcopenia vary across settings, such as in the community (1-29%), LTC facilities (14–33%), and among patients (10%) in acute care hospitals. A second systematic review revealed that the prevalence of sarcopenia in the older adults ranged from 0.0% to 85.4% in men and 0.1% to 33.6% in women (Pagotto & Silveira, 2014).

Sarcopenia is a public health problem, and preventing disability in older adults is a national priority (Bruyère et al., 2016; Ferrucci et al., 2004). The reduction of muscle mass, strength, and function leads to a cascade of negative health outcomes including the loss of physical function, which represents the major prognostic indicator for the development of physical disability (Bruyère et al., 2016; Janssen, Heymsfield, & Ross, 2002). This loss begins with weakness of the lower extremities which contributes to difficulties in rising from a chair and getting out of bed, slow gait speed, balance problem, and falls (Barbat-Artigas et al., 2013; Kamel, 2003; Mijnarends et al., 2015).

With advancing age, sarcopenia-related impairment in physical function becomes severe and leads to increased risk for falls, reduced ability to perform activities of daily living, increased use of LTC facilities and nursing homes, hospitalization, and morbidity and mortality (Bruyère et al., 2016; Clark & Manini, 2010; Cruz-Jentoft et al., 2010; Hirani et al., 2015; Janssen, 2010; Morley, 2012; Newman et al., 2006). These negative consequences decrease the quality of life of older adults and result in a substantial increase in healthcare costs (Bruyère et al., 2016; Morley, 2012). Sarcopenia has been estimated to cost the United States health system around $18.5 billion a year (Bruyère et al., 2016). As the aging population increases, the negative impact of sarcopenia on the elderly and the healthcare system is projected to rise (Bruyère et al., 2016; Janssen et al., 2004).

According to the Administration on Aging (2012), older adults 65 years of age and older are expected to increase from 43.1 million in 2012 to 79.7 million by 2040 and older adults over the age of 85 years will triple from 5.9 million in 2012 to 14.1 million by 2040. Once sarcopenia-related functional decline becomes apparent in this population, older adults will have difficulty recovering from it (Cruz-Jentoff, et al., 2010). Thus, nurses and other healthcare professionals have a pivotal role to play in improving muscle mass, strength, and function and preventing disability in older adults. Knowledge about the risk factors for muscle weakness and impaired muscle function is important to develop tailored intervention programs that ameliorate the antecedents and muscle strength and function themselves. This knowledge can also consequently prevent disability and improve mobility in older adults and decrease healthcare costs.

Assessment of Muscle Function in Older Adults: Measurement Issues

Increased dependency and impairments are considered a major reason for transfer from RCACs to more restrictive living environments such as LTC and nursing homes. Researchers suggested that increased impairments may be related to a lack of appropriate assessment and treatment (Giuliani et al., 2008; Roberts et al., 2013). Most studies on RCACs residents only report general functional ability such as Activities of Daily Living (ADL), and there are no benchmarks for functional data (Giuliani et al., 2008; Kerse, Butler, Robinson, Todd, 2004; Roberts et al., 2013; Zimmerman et al., 2005). Although measures of ADL are valuable for identifying disability level, they are not useful for detecting modifiable muscle function impairments and functional limitations that lead to disability (Gibson et al., 2010; Giuliani et al., 2008). Therefore, performing more sophisticated assessment of muscle function is needed to identify limitations, understand the predictive value of specific impairments, and to target intervention modalities in older adults living in RCACs (Giuliani et al., 2008; Guralnik et al., 1994). Measures that provide more specific information regarding the muscular function include Muscle Mechanography (MM), the Short Physical Performance Battery (SPPB), and the Timed Up and Go (TUG) (Buehring et al., 2010; Guralnik et al., 1994; Minneci et al., 2015).

Understanding with precision the muscle function of older adults living in RCACs is important. It provides the ability to distinguish older adults at risk for placement into LTC facilities or nursing homes due to sarcopenia and the sequelae of sarcopenia from those who are more likely to successfully age in their home environment. Knowledge of this at-risk group may also assist in developing interventions to improve or maintain functional status and prevent or delay transfer to more restrictive living environments. Maintaining or improving functional status is associated with enhanced quality life and decreased use of expensive healthcare services (Fielding et al., 2011; Giuliani et al., 2008).

A new technology such as MM provides the possibility to obtain precise measures of muscle function and benchmarks for functional data (Buehring et al., 2010; Siglinsky et al., 2015). MM was developed to overcome some shortcomings of the traditional muscle function tests and to provide an objective quantification of muscle function (power and force) by using maximal two-leg maximal countermovement jumps, serial hopping, or heel raises performed on a ground reaction force platform. MM has been used in research and clinical settings (Buehring et al., 2010; Siglinsky et al., 2015). However, data comparing MM with traditional muscle function tests is limited and more research is needed to validate MM with other widely used muscle function tests in older adults (Buehring et al., 2015; Rittweger, Schiessl, Felsenberg, & Runge, 2004; Siglinsky et al., 2015). This study will examine the relationship between MM and other traditional muscle function tests including SPPB, TUG, and grip strength.

The Individual and Family Self-management Theory

The selection of a theoretical framework is critical to quantitative research as it provides the rationale for investigating a particular research problem. This study will use the theoretical foundation provided by the individual and family self-management theory (IFSMT) (Ryan & Sawin, 2009; Ryan & Sawin, 2013). According to the IFSMT, self-management is a process by which individuals and families use knowledge and beliefs, self-regulation skills and abilities, and social facilitation to achieve health-related outcomes (Ryan & Sawin, 2009). The IFSMT can potentially provide greater insight into the self-management behaviors in older adults to prevent sarcopenia and improve muscle outcomes. The IFSMT can provide a framework for assessing, planning, and implementing a theory based approach to the care of older adults and facilitate optimal health outcomes, particularly muscle mass, strength, and function. The IFSMT is depicted in Figure 1.

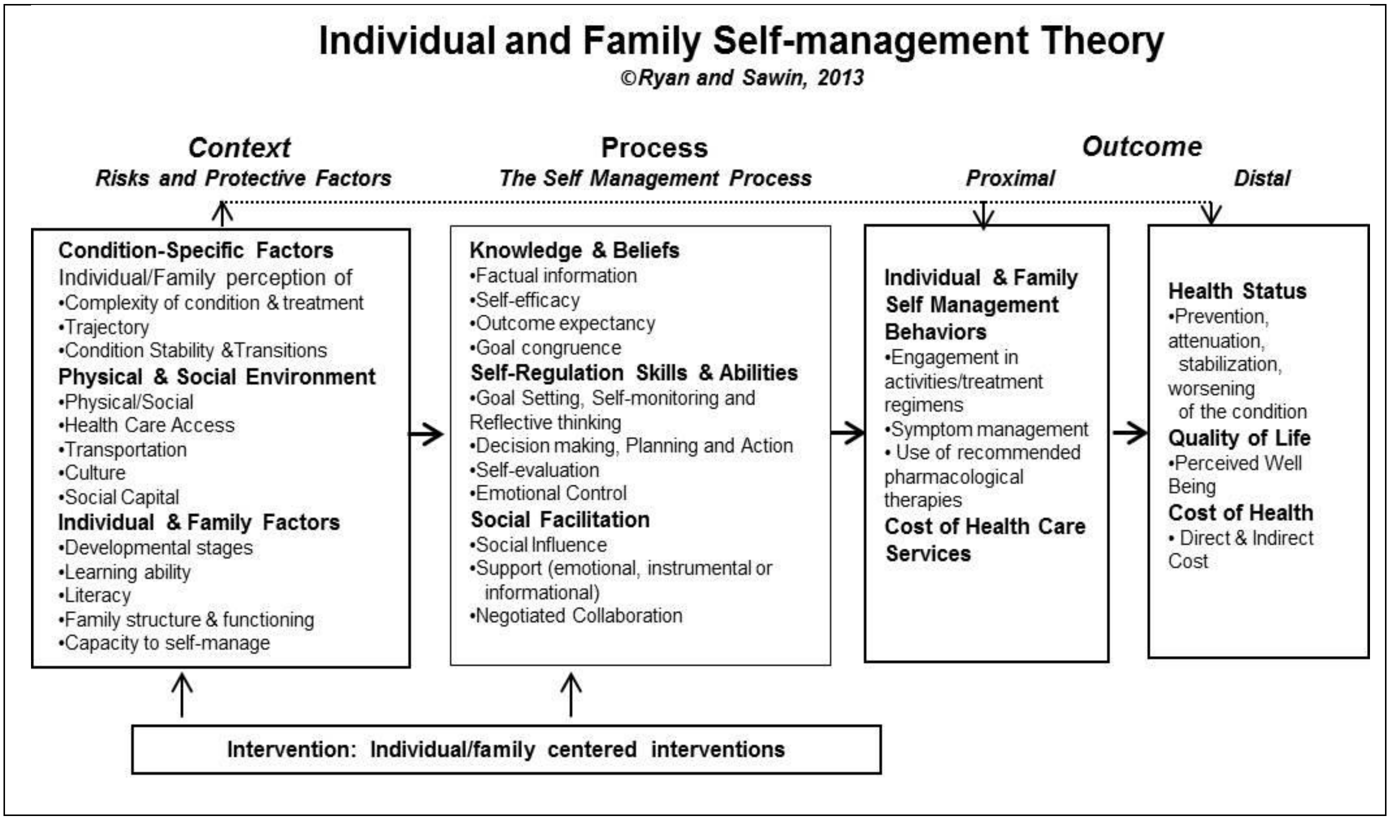


Figure 1. The Individual and Family Self-Management Theory.

The premise of the IFMST is that self-management is a complex dynamic phenomenon consisting of three dimensions: context, process, and outcomes (Ryan & Sawin, 2013). The theory incorporates cognitive and psychosocial concepts, such as self-efficacy, depression, and social support, which are relevant to identifying potential risk factors that contribute to sarcopenia in older adults. Ryan and Sawin (2013) postulate that contextual and process factors influence individual and family engagement in the process of self-management and these factors are antecedent to proximal and distal outcomes. Enhancing the individuals' and families' self-management processes leads to more positive health outcomes (Ryan & Sawin, 2013). Contextual factors include risks, protective, and individual factors such as depression and social support. The process factors (or the process of self-management) is influenced by concepts that affect individuals' knowledge and beliefs in their abilities such as the level of self-efficacy. The self-management behaviors are noted as a proximal outcome such as engaging in physical activity, managing depression, and developing a strong social network. Distal outcomes include health status (e.g., muscle mass, strength, and function), quality of life, and direct and indirect healthcare costs (Ryan & Sawin, 2013). Self-efficacy, depression, and social support concepts are selected for inclusion in the theoretical framework and are identified in the next section.

Introduction to Potential Risk Factors for Sarcopenia

The IFSMT model has been used to explain the self-management of calcium and vitamin D intake in women with osteoporosis (Ryan, Maierle, Csuka, Thomson, & Szabo, 2013). The model was also used to describe the self-management of medications in frail older adults receiving home healthcare services (Marek et al., 2013). However, the IFSMT model has not been used to study the potential risk factors for sarcopenia in older adults. The IFSMT has been modified to provide the foundational concepts for this research and to focus on concepts that might be relevant to the development of sarcopenia in older adults (Figure 2).

The decline in muscle mass, strength, and function has a complex and multifactorial etiology, which contributes to the phenomenon of sarcopenia (Cruz-Jentoft et al., 2010; Fielding et al., 2011; Morley, 2012). Although evidence has shown that malnutrition and physical inactivity are associated factors for sarcopenia, limited evidence was found about other potential factors including self-efficacy for exercise, depression, and social support. These factors have received less attention in this area of research and require further study (Brady et al., 2014; Campbell & Vallis, 2014; Goisser et al., 2015; Henwood et al., 2014; Kim et al., 2011). If the relationship between self-efficacy for exercise, depression, and social support to sarcopenia could be better understood and addressed, it could positively impact muscle outcomes and functional status in older adults.

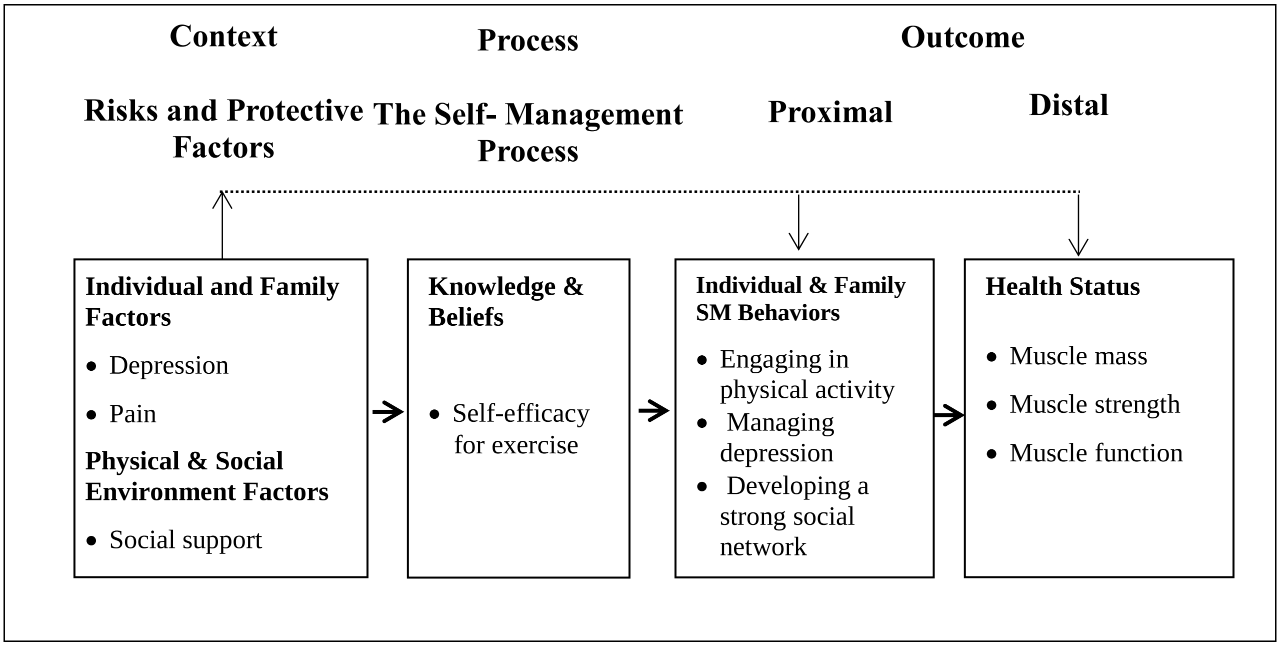


Figure 2. Application of Individual & Family Self-management Theory on Sarcopenia.

Physical activity. There is considerable evidence that exercise and physical activity are effective approaches to decrease the decline in muscle mass, strength, and function (Cruz-Jentoft et al., 2014; Cruz-Jentoft et al., 2010; Morley, Anker, & Haehling, 2014). Physical activity causes the muscles to contract, and that contraction stimulates the release of muscle growth factors (insulin growth and mechanogrowth factors). Release of muscle growth factors activates satellite cells and enables protein synthesis, which in turn, leads to muscle regeneration (Cruz-Jentoft et al., 2010, Kamel, 2003; Morley, 2012). People who are physically inactive or lead a sedentary lifestyle are less likely to stimulate the muscle regeneration process, making them more susceptible to developing sarcopenia (Gianoudis, Bailey, & Daly, 2014; Morley, 2012).

New research shows that sarcopenia is less likely to be present among individuals with high levels of physical activity and that physical inactivity is predictive of sarcopenia in older adults (Figueiredo et al., 2014; Landi et al., 2012; Lee et al., 2007). In addition, sarcopenia was less likely to be present among participants with high levels of physical activity. Gianoudis et al. (2014) reported that greater overall sitting time is associated with an increased risk of sarcopenia. Therefore, researchers need to further explore which factors might underlie any effects of physical activity on muscle outcome and physical function in older adults to guide and implement tailored intervention programs designed for this population.

Self-efficacy. The concept of self-efficacy was first introduced by Albert Bandura as a result of his psychological research in 1977. Self-efficacy is defined as people's judgments of their capabilities to carry out courses of action required to attain designated types of performances (Bandura, 1977). Self-efficacy has been considered a strong predictor for the level of physical activity and consistently associated with physical activity and well-being of older adults (Goisser et al., 2015; McAuley et al., 2011). Self-efficacy can enhance or impede the motivation to exercise and be active. Older adults with a high level of self-efficacy are able to set and achieve specific physical activity goals. These individuals have the commitment to engage in routine physical activity regimens for a sustained period of time. In contrast, low self-efficacy among older adults is associated with failure to engage in specific physical activity regimens for a sustained period of time leading to physical inactivity and sedentary lifestyle (McAuley et al., 2011).

Older adults may not have a high level of self-efficacy that is required to engage in routine physical activity regimens. Likewise, if older adults do not believe that engaging in physical activities will make difference in their mobility and muscle outcomes, they may lack outcome expectancy and have low levels of self-efficacy (McAuley et al., 2011). Additionally, falls are considered a major public health problem and a main cause of morbidity and immobility in older adults, particularly among RCACs and nursing homes residents (Berry & Miller, 2008). Falls may increase fear of injury, which leads to low self-efficacy and self-imposed limitation of activity (Berry & Miller, 2008), and consequently negatively influences muscle outcome and physical function in older adults.

Depression. Depression, which is both prevalent and undertreated in older adults, has deleterious consequences among older adults. Depression can negatively influence mobility, cognitive function, perceived self-efficacy, and self-management behaviors (Cramm et al., 2012; Fiske, Wetherell, & Gatz, 2009). Evidence shows that depression is a significant risk factor for development of sedentary lifestyle and decreased level of physical activity due to low motivation (Fiske et al., 2009; Roshanaei-Moghaddam, Katon, & Russo, 2009). As depression is strongly associated with physical inactivity and immobility, there may be an association between depression and sarcopenia.

Depression also compromises the nutritional status of older adults (Fiske et al., 2009), and consequently triggers substantial muscle loss. Recent studies demonstrated that malnutrition is significantly associated with sarcopenia in community-dwelling older adults (Landi et al., 2012; Santos et al., 2015; Volpato et al., 2014). Studies have shown that proper body mass index (BMI) and adequate protein intake are important for proper muscle mass and function and these are also key components of prevention and management of sarcopenia (Bauer et al., 2013; Beaudart et al., 2014; Cruz-Jenoft et al., 2010; Morley et al., 2010; Muir & Montero-Odasso, 2011).

Additionally, the literature indicates that depression and malnutrition can activate the immune system, which increases the production of inflammatory cytokines and C-reactive protein. Activating the inflammatory processes amplifies chronic catabolic conditions and reduces muscle mass in older adults (Alexandre, Duarte, Santos, Wong, & Lebrão, 2014; Cesari et al., 2004). Hence, because depression shares a relationship with known risk factors associated with sarcopenia (physical inactivity, malnutrition, and inflammatory processes), there may also be an association between depression and sarcopenia. Depression, when in combination with other factors, such as increasing old age, co-morbidities, and inadequate social support, can serve to compound and accelerate difficulties experienced with muscle mass, strength, and function.

Social support. Social support has captured the attention of gerontology researchers who seek to understand how this multi-dimensional concept influences the aging process of older adults. Social support can be defined as "information leading the subject to believe that he is cared for and loved, esteemed, and a member of a network of mutual obligations" (Cobb, 1976). One of the primary dimensions of social support is the structural dimension, which refers to individuals' degree of social involvement or embeddedness and the composition and size of their social network (Chen & Silverstein, 2000). Family and friends are an important source of support for older adults with chronic conditions that leads to greater adherence to self-management (Chen & Wang, 2007). Social support system functions as an environmental resource that facilitates self-management by meeting social interaction needs and enhancing an individual's motivation.

Social support is considered one of most important factors that impacts the relationship between self-efficacy and self-management behaviors and predicts the physical health in older adults (Gallant, 2003). Being in a supportive social network leads to beneficial effects on motivation, coping, psychological well-being, and self-management (Chen & Wang, 2007; Gallant, 2003). People experience different life-course exposures and daily life events that threaten their ability to perform the activities of daily living in a normal manner or engage in physical activity/exercise regimens (Yeom, Fleury, & Keller, 2008). While older adults who have strong social support are less likely to lead inactive lifestyles and be depressed, individuals with poor social support systems are prone to be isolated, depressed, and inactive (Wallace, Theou, Pena, Rockwood, & Andrew, 2015; Yeom et al., 2008). These negative consequences of poor social support may negatively impact physical function and muscle outcome in older adults. Strong and effective social support systems for older adults are related to a reduced risk for mobility deficits and depression, suggesting that strong social support may reduce or prevent disability in older adults (Wallace et al., 2015; Yeom et al., 2008).

Pain. While pain is not a normal part of aging, it is experienced daily by a majority of older adults due to chronic conditions such as osteoarthritis, rheumatoid arthritis, and neuropathic disorders. Undertreated pain in older adults has significant functional, cognitive, and emotional consequences (Kovach, 2013). Pain was also found to be a factor that reduces physical activity and directly contributes to the progression of sarcopenia in older adults (Scott, Blizzard, Fell, & Jones, 2012). Since pain is associated with sarcopenia, pain must be considered in this study and there is a need to control for the influence of pain when examining the relationship between self-efficacy for exercise, depression, and social support in regards to sarcopenia.

In summary, the adapted theoretical framework based on the IFSMT is a dynamic framework that shows the interactive relationship between self-efficacy for exercise, depression, and social support in regards to sarcopenia. The framework shows that self-efficacy for exercise, depression, and social support may contribute to sarcopenia in older adults. This adapted framework also reveals how these factors may influence muscle mass, strength, and function in older adults. Accordingly, the adapted theoretical framework represents a logical and dynamic design that could be useful to describe and explain the phenomenon of sarcopenia and its associated risk factors in older adults living in RCACs. Ultimately, this framework will also inform the research design, data collection and analysis, and discussion of the implications.

Other Terms/Definitions

Bioimpedance spectroscopy (BIS). A device used to measure the body composition of lean body mass (Yamada et al., 2013).

Convergent validity. The extent to which different tools that are designed to measure the same construct correlate with each other (Polit & Beck, 2012).

Muscle function. The basic function of a muscle in generating power and force. Muscle power is the product of force production and the velocity at which the force is produced. Muscle force is the total force required of muscles to move the body (Buehring et al., 2010).

Muscle mechanography (MM). A novel method that provides an objective quantification of muscle function parameters including muscle power and muscle force (Taani, Kovach, & Buehring, 2010).

Muscle mass. The body composition of lean body mass (Buehring et al., 2010).

Muscle strength. The ability of a muscle or muscle group to exert a maximal force or torque at a specific velocity during a muscle contraction (Verbrugge & Jette, 1994). Muscle strength in this study refers to handgrip strength, which is the maximal amount of force the dominant hand can produce isometrically. Handgrip strength is measured by using a hand dynamometer.

Residential care apartment complexes (RCACs). Facilities licensed by the state at a non-nursing home level of care, which provide room, board, 24-hour oversight, and minimal hours of assistance with activities of daily living (Giuliani et al., 2008).

Sarcopenia. The reduction in muscle mass, strength, and function in older adults (Morley, 2012).

Short physical performance battery (SPPB). A traditional muscle function test that consists of: gait speed as determined by a four-meter walk, timed repeated chair rises, and standing balance tests (Guralnik et al., 1994).

Timed up and go (TUG). A timed assessment of muscle function and mobility. It measures the time that an individual takes to rise from a chair, walk three meters, turn around, walk back to the chair, and sit down (Podsiadlo & Richardson, 1991).

Gaps in Nursing Knowledge

The relationship of self-efficacy for exercise, depression, and social support on muscle mass, strength, and function in older adults, particularly among RCACs residents, cannot be reasonably inferred from the existing literature. Although some risk factors such as nutrition and physical activity have been examined in several studies (Alexandre et al., 2014; Figueiredo et al., 2014; Kim et al., 2011; Landi et al., 2012; Lau, Lynn, Woo, Kwok, & Melton, 2005; Lee et al., 2007; Santos et al., 2015; Senior, Henwood, Beller, Mitchell, & Keogh, 2015; Tasar et al., 2015; Volpato et al., 2014; Yalcin et al., 2015), other potential risk factors have received less attention, particularly self-efficacy for exercise, depression, and social support. Limited studies have been previously conducted at nursing homes (Landi et al., 2012; Senior et al., 2015; Tasar et al., 2015); however, it is not clear whether the results of these studies can be generalized to RCACs residents. To the best knowledge of the author, there is no nursing study that has yet examined the relationship between the aforementioned cognitive and psychosocial factors and sarcopenia in older adults living in RCACs. In addition, although the most current literature explores the relationship between a few potential risk factors and sarcopenia in older adults, previous studies have lacked a theoretical framework or conceptual model to guide their research design and methodology.

Furthermore, measures of ADL are not useful to identify the modifiable functional impairments and limitations that contribute to disability (Gibson et al., 2010; Giuliani et al., 2008). One study found that most of the RCACs residents who were reportedly independent in ADL they had substantial mobility problems based on actual functional performance (Giuliani et al., 2008). However, most studies on RCACs residents in the United States still report general data about functional ability such as ADL without reporting benchmarks for functional data of this population (Giuliani et al., 2008; Roberts et al., 2013). There is limited knowledge about the muscle function characteristics of RCACs residents that based on muscle function measures. In addition, using a new technology such as MM to obtain precise measure of muscle function and benchmarks for functional data in older adults is important (Buehring et al., 2010; Rittweger et al., 2004). However, there is paucity of data comparing MM with other widely used traditional muscle function tests in older adults (Buehring et al., 2015; Rittweger et al., 2004; Siglinsky et al., 2015). This study will fill these gaps.

Study Purpose

The purpose of this dissertation study is threefold: 1) to describe the characteristics of muscle mass, strength, and function in older adults living in RCACs; 2) to determine, after controlling for pain, whether there is a difference in muscle mass, strength, and function among older living in RCACs based on self-efficacy for exercise, depression, and social support levels;

and 3) examine the convergent validity of MM parameters with widely used traditional muscle function tests (SPPB, TUG, and grip strength).

Research Questions and Hypotheses

The research questions that will be addressed in this study include:

1) What are the self-efficacy for exercise, depression, social support of older adults living in RCACs?
2) What are the muscle mass, strength, and function of older adults living in RCACs?

The hypotheses for this study include:

1) Participants with high self-efficacy for exercise will have greater muscle mass, strength, and function than participants with low self-efficacy for exercise.
2) Participants who do not have depression will have greater muscle mass, strength, and function than participants who have depression.
3) Participants with high social support will have greater muscle mass, strength, and function than participants with low social support.
4) Weight corrected jump power obtained by MM correlates well with other traditional muscle function and strength tests, including SPPB, TUG, and grip strength.

The findings of this study could contribute to the design of a tailored, nurse-driven, multicomponent intervention that could minimize sarcopenia, prolong independent mobility, and delay LTC placement among RCACs residents.

Contributions to Nursing and Innovation

This study will add to the nursing knowledge by examining potential risk factors for sarcopenia that have not been studies in previous research among older adults living in RCACs.

It will also provide a better understanding of muscle mass, strength, and function characteristics in older adults by using sophisticated technology including MM and BIS. MM and BIS tools, along with other traditional measures, will be used to assess muscle function and muscle mass, respectively. This study is among the first to focus on using highly innovative technology to quantitatively measure health outcomes in nursing research. The National Institute of Nursing Research has emphasized extending nursing science through the integration of biological sciences and supporting and employing new innovative technologies for research questions and methods (National Institute of Nursing Research [NINR], 2011). New technology generates opportunities to nursing researchers to move the nursing field forward and optimize patients' health outcomes.

The preliminary findings of this study could help on how best to further expand our current understanding of factors associated with sarcopenia and unsuccessful aging. The finding could also inform researchers and policy makers on how to best develop, test, and implement a multi-component nurse-driven intervention that could improve muscle function, prevent disability, and delay LTC placement among RCACs residents, and subsequently decrease healthcare costs.

Study Setting and Sample

This study is a secondary data analysis using a cross-sectional design from a randomized, crossover design study that investigated the effect of semi-recumbent vibration therapy on muscle mass, strength, and function in older adults age 70 and older. Participants were recruited from a RCAC located in the Midwestern United States. Participants completed several questionnaires and tests including Self-Efficacy for Exercise (SEE) Scale, Geriatric Depression Scale (GDS), Lubben Social Network Scale (LSNS), muscle mass (body composition), two-leg maximal countermovement jump, SPPB, TUG, and grip strength tests. This secondary data analysis provides further analyses, interpretations, conclusions, and knowledge from the primary study. The author of this dissertation was the primary coordinator for the primary randomized controlled trial study. He was responsible for all aspects of study conduct to include recruitment, consent, scheduling exercise sessions, and coordinating testing visits.

Chapter Summary

This chapter introduced the importance of identifying the associated factors for sarcopenia and understanding the functional characteristics of older adults living in RCACs. The Individual & Family Self-management Theory (Ryan & Sawin, 2009) was adapted as a theoretical framework for this dissertation study. Self-efficacy for exercise, depression, and social support are factors that could influence the development and progression of sarcopenia and disability in RCACs residents. This dissertation study will provide new knowledge about the relationship between these factors and sarcopenia, muscle function characteristics, and new technology to assess muscle function in older adults living in RCACs. This knowledge is important to develop new intervention to improve muscle outcome and functional status, and to delay long-term placement of older adults living in RCACs.

CHAPTER 2

Introduction to the Chapter

In this chapter of this non-traditional dissertation, two manuscripts are presented. The first manuscript is a literature review that discuss the current state of knowledge regarding the associated risk factors for sarcopenia in older adults. Several studies that explore the risk factors for sarcopenia in older adults are examined. The second manuscript presents Muscle Mechanography (MM) as a novel method that can be used to quantitatively assess muscle function in older adults. MM is presented as a safe and useful method that appears to have more precision and reliability than more commonly used muscle function tests.

Section 2.1-Manuscript 1

Risk Factors for Sarcopenia in Older Adults: A Review of Literature

Introduction

Sarcopenia is an important geriatric syndrome characterized by generalized and progressive reduction in muscle mass, strength, and function that is associated with aging (Cruz-Jentoft et al., 2010). The reduction in muscle mass typically starts at the age of 40 years, where approximately 8% of muscle mass is lost per decade until the age of 70 years. The loss accelerates to reach 15% per decade after age 70 and this reduction negatively affects muscle strength and function (Grimby & Saltin, 1983). The reduction in muscle mass, strength, and function is one of the most common causes of declines in mobility and increases dependency in older adults. This reduction also significantly reduces the ability of older adults to perform activities of daily living (ADL) and increases the risk of fall, loss of bone mineral density, and fractures (Cruz-Jentoft et al., 2010).

The implications of sarcopenia in the older adults have been reported extensively in the literature. Due to the changes in muscle mass, strength, and function that accompany aging and that are related to many interrelated factors, older adults are at increased risk for accelerated muscle loss and weakness, which contributes to functional decline, physical disability, and loss of independence. This consequently leads to increased healthcare services utilization, institutionalization, and healthcare costs (Cruz-Jentoft et al., 2010; Janssen et al., 2004).

Sarcopenia is highly prevalent among older adults in both genders worldwide (Cruz-Jentoft et al., 2014; Janssen et al., 2004; Pagotto & Silveira, 2014). Estimates based on the prevalence of sarcopenia and on the World Health Organization population data suggest that more than 50 million of older adults are affected by sarcopenia, and the number is expected to increase to more than 200 million over the next 40 years (Bruyère et al., 2016). In 2000, the World Health Organization reported that the number of people around the world aged 60 years and older was around 600 million and the number is expected to rise to 1.2 billion by 2025 and 2 billion by 2050 (Bruyère et al., 2016). In the United States, the number of individuals over 65 years old is predicted to increase to over 70 million by 2030 due to two factors: longer life spans and aging baby boomers (Administration on Aging, 2012). Hence, the prevalence of sarcopenia and its negative outcomes among older adults and the healthcare system is expected to increase, which underscores the importance of sarcopenia diagnosis and prevention in older adults.

Sarcopenia has many causes and can be observed in both young and older adults (Cruz-Jentoft et al., 2010; Pagotto & Silveira, 2014). Sarcopenia can be classified into two categories: primary and secondary sarcopenia. Sarcopenia can be considered primary or age-related when no other causes are evident but aging itself. Secondary sarcopenia is the term used when one or more causes for changes in muscle mass and function are identified such as chronic illnesses, malnutrition, cachexia, chronic inflammation, muscle disuse, and physical inactivity (Cruz-Jentoft et al., 2014). The cause of sarcopenia in many older adults is multifactorial so that it may not be possible to describe each individual as having a primary or secondary sarcopenia. This situation is consistent with recognizing sarcopenia as a multi-faceted geriatric syndrome (Cruz-Jentoft et al., 2010; Cruz-Jentoft et al. 2014; Landi et al. 2012).

Whereas several mechanisms for the development of sarcopenia are well understood (e.g., hormonal alterations, protein synthesis, proteolysis, and endocrine issues), the role of cognitive factors (e.g., self-efficacy) and psychosocial factors (e.g., depression and social support) on the onset and progression of sarcopenia are currently poorly understood (Brady et al., 2014; Campbell & Vallis, 2014; Goisser et al., 2015; Henwood et al., 2014). Understanding risk factors and mechanisms of action can potentially assist in identifying early markers for sarcopenia prevention. Identifying the modifiable risk factors for sarcopenia is pivotal to developing and implementing therapeutic interventions to reduce the negative consequences of sarcopenia including disability, institutionalization, falls, fractures, and death. While knowledge gaps remain, there is some evidence that several factors may contribute to the phenomenon of sarcopenia in older adults (Brady et al., 2014; Fielding et al., 2011; Goisser et al., 2015; Henwood et al., 2014).

The purpose of this manuscript is to review the literature that describes the factors associated with sarcopenia in older adults. A search for relevant literature was conducted using the Cumulative Index to Nursing and Allied Health Literature (CINAHL), PubMed, and PsychInfo using keywords ‘sarcopenia’, ‘muscle mass’, ‘muscle strength’, ‘muscle function’, ‘older adults’, ‘elderly’, ‘residential care apartment complexes (RCACs)’, ‘nursing homes’, ‘risk factors’, ‘psychosocial factors’, ‘cognitive factors’, ‘self-efficacy’, ‘depression’, and ‘social support'. A total of 172 articles were retrieved. Inclusion criteria consisted of relevant, full-text English language research studies in older adults aged 60 years and older, resulting in 21 articles to be reviewed.

Methods

The databases searched for relevant literature were CINAHL, PubMed, and PsychInfo. Keywords for this preliminary search included 'sarcopenia', 'muscle mass', 'muscle strength', 'muscle function', 'older adults', 'elderly', 'residential care apartment complexes (RCACs)', and 'nursing homes'. Over 3,400 articles were identified. Additional terms were used to refine the search including keywords 'risk factors', 'psychosocial factors', 'cognitive factors', 'self-efficacy', 'depression', and 'social support'. The search was limited to relevant, English language papers published between 2000 and 2016. Due to the paucity of studies among older adults living in RCACs, the criteria for considering studies were broadened to include studies that identified associated factors for sarcopenia in community-dwelling older adults, assisted living facility residents, and nursing home residents aged 60 years and older. This refined search resulted in 172 articles of which the titles and abstracts were screened for inclusion criteria. Reference lists of relevant articles were screened for other potentially eligible studies. A total of 21 studies met the inclusion criteria and were extracted for review. The outcomes obtained from a review of the literature are illustrated in Appendix A.

Results

Physical Activity

Several correlational, cross-sectional studies explored the relationship between physical activity and sarcopenia in community-dwelling older adults (Alexandre et al., 2014; Castillo et al., 2003; Figueiredo et al., 2014; Gianoudis et al., 2014; Lee et al., 2007; Senior et al., 2015;

Volpato et al., 2014), and nursing home residents (Landi et al., 2012; Senior et al., 2015; Tasar et al., 2015; Yalcin et al., 2015). The International Physical Activity Questionnaire-Short Form, Barthel Index of Activities of Daily Living, and Physical Activity Scale of the Elderly were used as tools to assess physical activity level.

Most of these studies show a negative association between physical activity and sarcopenia and that sarcopenia is less likely to be present among older adults with high levels of physical activity. The presence of sarcopenia was also inversely associated with involvement in daily leisure physical activities. In addition, Hsu and colleagues conducted a correlational, cross-sectional study in a veterans retirement community and found that low level of ADL and physical dependence were significantly associated with sarcopenia in older men (Hsu et al., 2014). One correlational, cohort, longitudinal study also revealed that low physical activity is significantly associated with the development of sarcopenia in community-dwelling older adults. The results of the protective effect of physical activity indicate a need for intervention and that increasing physical activity could be beneficial in preventing sarcopenia (Yu et al., 2014).

However, only a few studies showed no significant association between physical activity level and sarcopenia among community-dwelling older adults (Volpato et al., 2014; Alexandre et al., 2014), and nursing home residents (Tasar et al., 2015; Yalcin et al., 2015). However, the results of these studies have some limitations including selective healthy individuals and limited number of individuals with sarcopenia which may led to small statistical power and increased the probability of type II error.

Although resistance exercise and weight training are effective countermeasures to sarcopenia in older adults, vigorous exercise is not always required and moderate physical activity carried out as part of everyday activities and regular leisure activities (e.g., walking, gardening, and dancing) seem to be enough to reach considerable benefits among older adults (Figueiredo et al., 2014; Landi et al., 2010). In their correlational, cross-sectional study, Lee and colleagues reported that the Physical Activity Scale for the Elderly (PASE) score — a detailed record about physical activity involved in recreational, household, and social/voluntary work in a week time period — showed a significant association between physical inactivity and low appendicular muscle mass, which is an essential component of sarcopenia (Lee et al., 2007). In addition, a correlational, cross-sectional study examined the relationship between sedentary behaviors and musculoskeletal health and function in community-dwelling older adults found that greater overall sitting time is associated with an increased risk of sarcopenia (Gianoudis et al., 2014). Likewise, Senior and colleagues in their correlational, cross-sectional study found that setting time was predictive of sarcopenia in nursing home residents (Senior et al., 2015).

Self-efficacy. Although physical activity recommendations for older adults include both aerobic exercise and resistance-training, estimates indicate that only 51.1% and 21.9% of older adults meet the aerobic and resistance-training guidelines, respectively (Brady & Straight, 2014). Yet, most of older adults do not meet the recommended physical activity guidelines and engage in a sufficient volume of physical activity to promote health outcomes. Researchers assert that an important aspect very rarely addressed so far in sarcopenia research is the influence of self-efficacy (Brady et al., 2014; Goisser et al., 2015). An older adult with or without sarcopenia might not be easily integrated into a group-based exercise program and maybe prone to a sedentary lifestyle due to lack of self-efficacy. As research has demonstrated in behavioral change interventions, the role of self-efficacy is an important factor and is considered one of the strong predictors for the level of physical activity in older adults (Goisser et al., 2015). However, no studies found that examined the association between self-efficacy and sarcopenia in older adults.

Nutritional Status

Multiple correctional, cross-sectional studies have explored the association between nutritional status and sarcopenia in community-dwelling older adults (Alexandre et al., 2014; Figueiredo et al., 2014; Gariballa & Alessa, 2013; Kim et al., 2011; Lau et al., 2005; Lee et al., 2007; Santos et al., 2015; Volpato et al., 2014) and nursing home residents (Landi et al., 2012; Senior et al., 2015; Tasar et al., 2015; Yalcin et al., 2015). Body mass index (BMI) and the Mini Nutritional Assessment (MNA) tool were the two main methods used to evaluate nutritional status.

Most of the studies reported a negative association between malnutrition/BMI and sarcopenia (Alexandre et al., 2014; Figueiredo et al., 2014; Kim et al., 2011; Landi et al., 2012; Lau et al., 2005; Lee et al., 2007; Santos et al., 2015; Tasar et al., 2015; Yalcin et al., 2015). Hsu et al. (2014) also reported that low BMI was significantly associated with sarcopenia in older men living in a veterans retirement community. One correlational, retrospective, longitudinal study showed that malnutrition is significantly associated with sarcopenia in community-dwelling older adults and that high BMI is a predictor of sarcopenia (Murphy et al., 2013). Yu and colleagues conducted a correlational, cohort, longitudinal study and reported that low BMI is significantly associated with sarcopenia in community-dwelling older adults (Yu et al., 2014).

This review shows that sarcopenia is less likely to be present among participants who have a normal BMI, as well as an appropriate BMI is associated with higher muscle mass, muscle strength, and physical performance. In addition, older adults with sarcopenia are demonstrated to have a significantly lower BMI and poorer nutritional status than those without sarcopenia. A low BMI serves as an independent predictor of sarcopenia in both community-dwelling older adults and nursing home residents (Alexandre et al., 2014; Landi et al., 2012; Murphy et al., 2013; Yu et al., 2014). These results may have implications for development of interventions to improve nutritional status and improve muscle outcomes.

Depression

Several cross-sectional studies explored the association between depression and sarcopenia in community-dwelling older adults (Alexandre et al., 2014; Byeon, Kang, Kang, Kim, & Bae, 2016; Gariballa & Alessa, 2013; Han et al., 2016; Kim et al., 2011; Lee et al., 2007; Volpato et al., 2014), nursing home residents (Senior et al., 2015), and older men living in a veterans retirement community (Hsu et al., 2014). The GDS and the Center for Epidemiologic Studies Depression (CESD) scale were used to evaluate depression among the participants.

A positive association has been found between depression and sarcopenia in older adults, and depression was less likely to be present among older adults who have higher skeletal muscle mass (Gariballa & Alessa, 2013; Hsu et al., 2014; Kim et al., 2011). In a correctional, cross-sectional study among older men and women, individuals with self-reported depression or those taking antidepressants had lower muscle mass than those free of depression or antidepressant medications use (4.2 % lower in men and 3.7 % lower in women) (Kim et al., 2011). In another correlational, cross-sectional study included hospitalized patients aged 65 years and older, those identified with sarcopenia were more likely to be older, suffer from depression, and have a longer length of hospital stay (Gariballa & Alessa, 2013).

In contrast, the association between depression and sarcopenia was not detected in other studies. For instance, in a recent study included multiple age groups (20-39, 40-59, and ≥60 years) (N= 7,364), sarcopenia group did not have a higher prevalence of depression or depressive symptoms compared to the non-sarcopenia group, and all age groups showed no significant association between depression and sarcopenia (Byeon et al., 2016). Another correlational, cross-sectional study included 1,149 Brazilian community-dwelling older adults found no association between depression and sarcopenia (Alexandre et al., 2014). Other correlational, cross-sectional studies reported no association between depression and sarcopenia in community-dwelling older adults (Han et al., 2016; Lee et al., 2007; Volpato et al., 2014). Only one correlational, cross-sectional study conducted in a nursing home and found no relationship between depression and sarcopenia (Senior et al., 2015). Therefore, the literature has shown inconsistent results and conflicting reports about the association between depression and sarcopenia. Further studies are needed to assess the relationship between depression and sarcopenia among older adults.

Cognitive Impairment

Cognitive impairment has been linked to poor functional status and sarcopenia in older adults. Cognitive impairment commonly leads to sedentary lifestyle, bed rest, and malnutrition, which could trigger excessive muscle loss in older adults (Hsu et al., 2014). Cognitive impairment also causes neuronal changes in the central nervous system which alters the levels and activity of neurotransmitters, and consequently leads to a decrease in the motor units and the ability to maintain muscle activation (Walston et al., 2006).

Several correlational, cross-sectional studies explored the association between cognitive function and sarcopenia in community-dwelling older adults (Alexandre et al., 2014; Volpato et al., 2014), nursing home residents (Landi et al., 2012; Senior et al., 2015; Yalcin et al., 2015), and in older men living in a veterans retirement community (Hsu et al., 2014). The Mini-Mental State Examination and Cognitive Performance Scale were the most common methods used to evaluate the cognitive function among the participants. Two studies showed that cognitive impairment is associated with sarcopenia in older adults (Alexandre et al., 2014; Hsu et al., 2014). However, other studies showed no association between cognitive function and sarcopenia (Landi et al., 2012; Senior et al., 2015; Volpato et al., 2014; Yalcin et al., 2015). Yu and colleagues also found no significant associations between cognitive impairment and incident sarcopenia (Yu et al., 2014). Therefore, supporting data are still scarce and controversial, and the association between cognitive function and sarcopenia needs further investigation.

Social Support

Strong social support and high social participation are often considered in discussions about healthy aging. Researchers underscore the importance of understanding these factors and to identify means through which social support and social participation might be maintained, particularly among older adults (Cruz-Jentoft et al., 2010; Wallace et al., 2015; Yeom et al., 2008). Social support is a common risk factor associated with quality of life among older adults. Poor social support has negative impacts on physical, cognitive, and mental wellness, as well as on morbidity and mortality (Cruz-Jentoft et al., 2010; Wallace et al., 2015). Nonetheless, no studies were found that explore the relationship between social support and sarcopenia in older adults.

Only one study was found that examined the association between social participation and lower extremity muscle strength and gait speed in Americans aged 50 years and older (Warren, Ganley, & Pohl, 2016). The study revealed a significant association between social participation and gait speed among older adults who aged 65 years and older. Older adults with low social participation had three times higher odds of slower walking speed compared with those without a reported limitation with social participation (OR = 3.1; 99% CI [1.5–6.2]). The social participation was also significant with lower extremity strength and self-reported limitation in those 65 and older. These older adults had a significantly three times higher odds of being weak compared with strong (OR = 3.5, 99% CI [1.3–9.9]) (Warren et al., 2016).

Smoking and Alcohol Consumption

Multiple correlational, cross-sectional studies explored the relationship between smoking status and sarcopenia in community-dwelling older adults (Alexandre et al., 2014; Castillo et al., 2003; Figueiredo et al., 2014; Gabrilla & Alessa, 2013; Han et al., 2016; Lau et al., 2005; Lee et al., 2007; Martins, Bôas, & McLellan, 2016), and nursing home residents (Tasar et al., 2015). Self-reported questionnaires were used to assess smoking status among the participants. Smoking was reported as a risk factor for sarcopenia (Alexandre et al., 2014; Castillo et al., 2003; Figueiredo et al., 2014; Lee et al., 2007; Martins et al., 2016; Tasar et al., 2015). Alexandre et al. (2014) stated that smoking may reduce the ability of the already suffering system to obtain muscular energy, which may cause muscle fatigue and subsequently increase the protein catabolism that can reduce muscle mass and function (Alexandre et al., 2014). One correlational, longitudinal study showed no significant association between smoking status and sarcopenia in community-dwelling older adults (Murphy et al., 2013).

Other studies examined the association between alcohol consumption and sarcopenia using self-reported questionnaire in community-dwelling older adults (Castillo et al., 2003; Gabrilla & Alessa, 2013; Lau et al., 2005; Lee et al., 2007; Han et al., 2016), and nursing home residents (Tasar et al., 2015). The results did not support alcohol consumption as a risk factor for sarcopenia. However, only one study showed a significant association between daily drinking and sarcopenia in women, suggesting that chronic consumption may promote loss of muscle mass and strength in old age (Han et al., 2016).

Other Factors

A few correlational, cross-sectional studies explored the relationship between chronic illnesses and pain and sarcopenia. Several studies revealed that cerebrovascular disease, hypertension, osteoarthritis, and diabetes are factors associated with sarcopenia in older adults (Han et al., 2016; Landi et al., 2012; Lee et al., 2007). A correlational, longitudinal study also showed that stroke is associated with sarcopenia (Yu et al., 2014). Pain was also found to be a risk factor for sarcopenia in older adults. Murphy et al. (2013) assessed muscle mass, gait speed, and grip strength seven times over 9 years and found that pain is a predictor of transition from the normal state toward sarcopenia in older adults. The result may reflect avoidance of physical activity due to pain-related fear, as well as pain may indicate inflammation that contributes to muscle loss.

Critique of the Literature

The examined literature showed that the majority of the studies were conducted among community-dwelling older adults, whereas only a few studies focused on older adults living in nursing homes. Only one study conducted among older men living in a veterans retirement community and no studies found among assisted living facilities residents. Most of the studies were correlational with a cross-sectional design, which limits the ability to clarify any cause-effect relationships between sarcopenia and its associated factors. Detailed descriptions of the participants including sample size, age, gender, and demographic location from which the participants were recruited were discussed. However, many studies did not report how the effect size was justified.

The inclusion and exclusion criteria were clearly presented in most of the studies. However, several studies potentially introduced selection bias by excluding older adults living in institutions and those with mobility difficulties (e.g., individuals using walker), and representing only healthier, more physically active, and more educated individuals from the general population (Alexandre et al., 2014; Gariballa & Alessa, 2013; Lee et al., 2007; Murphy et al., 2013; Tasar et al., 2015; Volpato et la., 2014; Yalcin et al., 2015; Yu et al, 2014). Thus, it cannot be said that the sampling is necessarily representative of the overall older adult population. These limitations may also hinder the ability to detect associations between potential risk factors and sarcopenia. Interestingly, most of the studies were found on sarcopenia and its associated factors were current and published in the past 5 years, which indicates that interest in sarcopenia among older adults is growing among members of the scientific community and more research is needed in this area.

The majority of the measures and data collection procedures were clearly defined and described in the reviewed studies. However, the studies have several methodological issues. First, most of the studies have used traditional muscle function tests (e.g., gait speed, timed-up-and-go (TUG), and chair rise tests) to assess muscle function. These traditional measures have important limitations. These limitations include pass/fail determinations and timing variability resulting from examiner subjectivity. Older adults with significant disability may not be able to perform chair-rise or TUG test. Another limitation is that the traditional chair-rise test requires maximal power (watts) but is reported in seconds (Taani et al., 2017).

Second, the use of bioelectrical impedance spectroscopy (BIS) to measure muscle mass may lead to measurement errors because of the dehydration problems that can be observed in older adults. Decreasing the total body water may result in an underestimation of body fat and an overestimation of fat-free mass (Yamada et al., 2013). However, BIS is inexpensive, easy to use, reproducible, and considered a portable alternative to dual-energy X-ray absorptiometry (DXA)

(Yamada et al., 2013). Measure muscle mass in older adults using DXA is not feasible and BIA is a more practical method to use in large samples. Finally, one study did not find an association between physical activity and nutritional status and sarcopenia (Volpato et al., 2014). This unexpected result may due to misclassification in the self-report assessment of physical activity level and nutritional intake.

Discussion

Sarcopenia is considered a main cause for impaired physical function, dependency, and decreased quality of life (Morley, 2012). This underscores the importance of identifying the risk factors associated with sarcopenia and developing effective preventative interventions. This review shows that physical inactivity and malnutrition are risk factors for sarcopenia in older adults. These two factors were common across most of the studies. Although self-efficacy for exercise is considered one of the strong predictors for the level of physical activity in older adults (Goisser et al., 2015; Brady et al., 2014), the impact of self-efficacy has been rarely addressed in relation to sarcopenia and none of the studies examined the existence of such relationship.

Several studies showed that older adults with sarcopenia were more frequently diagnosed as malnourished than older adults without sarcopenia. Maintaining proper nutrition status and BMI along with adequate protein intake play a major role in preventing and managing sarcopenia in older adults (Alexandre et al., 2014; Landi et al., 2012; Yu et al., 2014). These results can be significantly important for conducting further research and designing effective interventions to improve nutritional status and prevent sarcopenia.

Studies shows that depression and cognitive impairment are inconsistently associated with sarcopenia. Limited studies reported a significant relationship between these two factors and sarcopenia (Alexandre et al., 2014; Hsu et al., 2014; Gariballa & Alessa, 2013; Kim et al., 2011). Depression and cognitive impairment may lead to malnutrition and sedentary lifestyle, which may contribute to muscle loss and development of sarcopenia (Hsu et al., 2014; Kim et al., 2011). However, evidence showed that the relationship between depression and cognitive impairment and sarcopenia is still poorly understood and further research is needed in this area.

Although researchers emphasized the importance of social support in the context of aging (Cruz-Jentoft et al., 2010; Wallace et al., 2015; Warren et al., 2016; Yeom et al., 2008), no studies explored the relationship between social support and sarcopenia. Furthermore, limited evidence was reported about the relationship between smoking status, alcohol consumption, pain, and chronic illnesses and sarcopenia. While limited studies in this review showed a significant association between smoking status and pain and sarcopenia, none of the studies showed a significant association between alcohol consumption and sarcopenia.

Conclusion and Gaps in Knowledge

This review revealed that the relationship of self-efficacy for exercise, depression, and social support on muscle mass, strength, and function in RCACs residents is poorly understood. Many studies have focused on common factors including physical activity and nutrition status and limited or no studies were found that addressed other potential factors including self-efficacy, depression, and social support. Several studies have also focused on identifying the risk factors for sarcopenia in community-dwelling older adults and no studies indicate that attention has been focused on RCACs residents.

To gain better understanding of the risk factors for sarcopenia among older adults living in RCACs, more studies need to be conducted in this at-risk group. Knowledge of this at-risk group is important to develop tailored interventions to prevent sarcopenia and its negative health consequences. Such interventions may also assist in improving or maintaining functional status and preventing or delaying transfer to more restrictive living environments, and consequently enhancing quality life of older adults and decreasing use of expensive healthcare services.

In addition, most the studies have used traditional muscle functions tests to assess muscle function among the participants. These tests have several limitations and more precise measurements of muscle function in older adults are needed. More research is need to address these gaps in the literature; to gain better understanding of the risk factors for sarcopenia in RCACs residents and provide knowledge about the muscle function characteristics of this at-risk group of older adults.

Section 2.2-Manuscript 2

Manuscript 2: Muscle Mechanography: A Novel Method to Measure Muscle Function in Older Adults

Introduction

Assessing muscle function in older adults has become an important topic in the field of geriatric research. Aging is associated with changes in body composition and functional capability, including a reduction in muscle mass and muscle function (Morley, 2012). These age-related reductions have been named sarcopenia (Fielding et al., 2011). Recent estimates indicate that up to 45% of older adults in the United States experience sarcopenia, depending on which population is studied and which definition is used (Janssen et al., 2004). Older adults with sarcopenia are at greater risk for falls, fractures, and head injuries (Buehring et al., 2010; Morley, 2012). Compromised muscle function in older adults was found to be an independent predictor of increased use of long-term care facilities, hospitalization, disability, and mortality (Clark & Manini, 2010; Hirani et al., 2015; Landi et al., 2013).

Assessment of sarcopenia requires measurement of muscle function. Key physical units necessary to quantify muscle function include: force (Newtons [N]), velocity (m/s), and power (watts [W]). Muscle force relates to the force exerted to get the body moving, or the direct muscle forces imparted to the skeleton during movement. Common tests assessing muscle force are grip strength or knee extensor strength. These tests require a maximal muscle contraction to create a peak force. Muscle force is one of the primary regulators of bone mass and an important determinant of bone and joint health in older adults. Muscle force is strongly correlated with bone strength, bone size, total bone area, and femoral neck bone mineral density (Hardcastle et al., 2014; Pojednic et al., 2012; Rantalainen et al., 2009; Runge & Hunter, 2006). Muscle velocity (or movement velocity) is the rate of motion (speed) in a specific direction. The best example of a test measuring velocity is the 4-m walk to assess gait speed. Velocity (e.g., gait speed) slows with aging and is a key component in the onset of functional impairments in older adults.

Muscle force and velocity are significant determinates of power production and functional task performance in older adults (Pojednic et al., 2012). Muscle power is defined as the ability to generate as much force as possible and as quickly as possible. It is calculated as the product of force and velocity. Thus, altered neural or muscular ability affecting either factor (force or velocity) will contribute to declines in power and potentially physical function (Pojednic et al., 2012). Examples of tests measuring power are the chair-rise test and two-leg maximal countermovement jumps. Muscle power is a valuable measure for identifying age-related physical impairments and strongly correlates with physical capability, mobility, the risk of falling, and sarcopenia (Caserotti, Aagaard, Simonsen, & Puggaard, 2001; Runge & Hunter, 2006; Rittweger et al., 2004; Siglinsky et al., 2015; Singh et al., 2014). Leg power is often corrected for body weight (W/kg).

Several traditional muscle function measures have been developed, validated, and used to assess muscle function in older adults (Siglinsky et al., 2015). Among these, gait speed is one of the most frequently used methods. It is measured as the time taken to walk 4 m or another distance achieved during a 2-minute timeframe. Gait speed is a predictor for falls, fractures, hospitalization, caregiver need, and mortality among older adults (Montero-Odasso et al., 2005; Studenski et al., 2011). The chair-rise test is measured by the time required to rise from a chair five times without using its arms. After first assessing if the individual is able to rise once successfully, he/she will be asked to rise from a chair five times and time to complete the five chair rises will be recorded. Repeated chair-rise performance is strongly related to fall and hip fracture risk among older adults (Cawthon et al., 2008). The grip strength test assesses muscle strength using a hand-grip dynamometer. Grip strength is associated with important clinical measures, including disability, length of hospital stay, postoperative complications, and mortality in older adults (Bohannon, 2015). Low grip strength is also associated with various causes of death, including myocardial infarction, stroke, fall, and fracture (Leong et al., 2015).

However, many of the traditional tests have limitations: they often cannot be used over a wide range of performance levels and have drawbacks for testing older adults who have very high or low functional ability. For example, self-selected usual gait speed has a ceiling effect because at some point the individual is walking at a faster pace than his/her usual pace or even jogging/running. The chair-rise test has a floor effect because individuals who cannot rise from the chair cannot be measured. Often these measures only examine particular aspects of muscle function (e.g., balance, power, force) and few provide a quantitative measure (e.g., force, velocity, power). For example, the traditional chair-rise test requires maximal power (W) but is reported in seconds (Buehring et al., 2013; Puthoff, 2008; Siglinsky et al., 2015). Other limitations of these tests include dichotomous (pass/fail) determinations and being prone to human errors as the final results depend on the times taken by individual examiners (Buehring et al., 2013; Siglinsky et al., 2015).

Therefore, quantitative methods for the precise measurement of muscle function in older adults over a broad range of performance is desirable. The National Institute of Nursing Research has emphasized extending nursing science through the integration of biological sciences and supporting and employing new innovative technologies for research questions and methods (NINR, 2011). These technologies should include methods to optimally assess muscle function in older adults. Muscle mechanography is an innovative technology that quantitatively assesses muscle function parameters in older adults using a ground reaction force platform (GRFP). The purpose of the current article is to introduce muscle mechanography as a method to assess muscle function in older adults. The review covers the mechanism of muscle mechanography, different types of tests, parameters that can be obtained by using muscle mechanography, measurement procedures, reproducibility, and safety.

Muscle Mechanography

Muscle mechanography can quantitatively assess muscle function (force, velocity, power, center of gravity/sway) using a GRFP. Movements that can be measured include heel rise, chair rise, hopping, jumping, and static balance positions (e.g., semi-tandem or tandem stance). A variety of GRFP systems have been used in research settings (Buehring et al., 2010; Matheson et al., 2013; Rantalainen et al., 2010; Rittweger et al., 2004; Singh et al., 2014). One of the most commonly used systems is the Leonardo Mechanograph®.

Principle of Measurement

The Leonardo Mechanograph GRFP comprises two symmetrical left- and right-sided force plates, which measure and quantify any asymmetries in individuals' physiological movements. A mass (e.g., body weight) creates a vertical ground reaction force on the plates, which elicits changes in electrical resistance in the GRFP's sensors that are proportional to the exerted force. The voltage changes are measured at a frequency of 800 Hz by four strain gauge force detectors located in each force plate (eight total force sensors). The collected voltage reading is transferred via a USB 2.0 connection to a personal computer running the Leonardo Mechanography software (Binkley & Specker, 2008; Matheson et al., 2013; Rittweger et al., 2004; Veilleux & Rauch, 2010). From the measured voltage and changes in voltage over time, the software can calculate other muscle function parameters, such as velocity and power. Several software versions are available and the most recent includes reference data for individuals ages 3 to 99 years.

Muscle Function Parameters Obtained Using Muscle Mechanography

Unlike traditional muscle function tests, muscle mechanography directly measures the applied force vector and calculates measures of force, velocity, power, jump height, and sway (i.e., the change of the center of gravity during a balance test) (Buehring et al., 2010; Matheson et al., 2013; Rittweger et al., 2004). The Leonardo system also reports the Esslinger Fitness Index, an age- and sex-adjusted measure of power assessed during countermovement jumps. Operational definitions of the variables available through Leonardo mechanography are presented in the Table 1.

Table 1

Operational Definitions of the Variables Available Through Muscle Mechanography

Variable	Definition
Force	The total force exerted on the platform to get the body moving, which also causes acceleration. Force is exerted by movements. Force is calculated by multiplying body's mass with its acceleration. Force (Newton) = mass (kg) x acceleration (m/s).
Velocity	Velocity is the rate of motion (speed) in a specific direction. It is calculated by integrating acceleration over time.
Power	Power is a necessary parameter to measure movement. Movement is the action of force along a specific distance in a certain time, which is measured as power. Power is also used to describe the rate at which energy is used. It is calculated by multiplying force and velocity. Power=force x distance/ time = force (N) x velocity (m/s).
Esslinger Fitness Index (EFI)	This is the performance of the movement. The EFI represents the maximum jump power relative to body weight for one's age (ages 3 to 99 years) and gender-matched reference population.
Jump height	

	Jump height is defined as the displacement of the body's center of gravity. Integration of velocity over time results in displacement of center of gravity/jump height.

Measurement Procedures

Platform Quality Assurance

Although no standardized procedure exists, it is the current authors' recommendation that the platform should be calibrated at least weekly to assure accuracy and precision of the static properties before performing any tests. In addition, it should be calibrated every time it is moved from one location to another. Three 20-kg Troemner cast iron grip handle weights were used for calibration in the current authors' studies. These weights are stacked in one corner of the platform and the measurement of the weight is recorded. This process is repeated for each of the other three corners. In addition, two weights are placed side by side in the middle of the platform with a third weight placed on top to obtain a central measurement. If any measurements are outside of the ±0.5-kg limit, recalibration is needed.

Test Procedures

Several tests and movements can be performed on the GRFP. All tests are generally easy to understand as they are natural movements that most individuals have performed throughout their lives (e.g., rising on the toes, rising from a chair, hopping/jumping). However, it is recommended that participants receive standardized instructions and that the tests be demonstrated by a trained staff member. In addition, older adults should wear a gait belt while performing tests and at least two staff members should be present to ensure the individual's safety. Staff should be ready to assist the participant who is wearing a gait belt in case he/she loses balance (Figure 3).

Figure 3. Example of Older Adult Performing a Countermovement Jump under supervision of two trained staff members.

Heel-rise test. The main outcomes of this test are velocity and power. The test comprises heel rises with the goal of achieving the maximum speed of their upward movement. After standing still on the force platform, participants should be instructed to rise on their tiptoes by lifting their heels from the force platform as quickly as possible after hearing a single-tone beep (Veilleux & Rauch, 2010). A double-audible tone indicates the end of the test. Participants are asked to perform three heel raises and the heel raise with the greatest height is used for analysis. This test is useful for older adults who have a degree of functional disability that limits their ability to participate in the jump and chair-rise tests.

Chair-rise test. The major outcomes of this test are force, velocity, and power. In addition, this test evaluates a movement that is highly relevant in everyday life (Veilleux & Rauch, 2010). A specific bench is installed on the force plate for the purpose of this test. After sitting on the bench with feet on the ground, participants are instructed to cross their arms over their chest, then stand up straight and sit down again as fast as possible. If participants rise successfully, they are instructed to repeat this five times as quickly as possible. These are exactly the same instructions as for the traditional chair-rise test, but muscle power is reported instead of time. The rise with the highest maximum power, or an average of several rises (three to five), is analyzed.

Single two-legged countermovement jump. This test has been extensively used among older adults in research settings (Buehring et al., 2010; Matheson et al., 2013; Rittweger et al., 2004; Runge et al., 2004; Siglinsky et al., 2015; Singh et al., 2014). The main outcome of this test is power (usually body weight corrected power [W/kg] is reported), but velocity and force can also be examined. To perform the test, participants stand on a platform, with a foot on each side, as still as possible. After standing still on the platform for at least 2 seconds, participants' body weight is recorded. Participants should be instructed to perform the jump as quickly and as high as possible, using both legs after hearing a single-tone beep. Participants should stand up straight and remain still after landing on the platform for at least 2 seconds until a double-tone beep indicates the end of the test (Buehring et al., 2010; Veilleux & Rauch, 2010). Participants can jump freely, without any arm movement restrictions (Figure 4). This procedure is repeated several times, with the goal to get three countermovement jumps deemed valid by the software. Participants should be given time to rest and recover between jumps. Depending on the participant's ability to lift off the platform completely and stand still before and after the jump, it might not always be possible to record three valid jumps. The jump with the greatest height is selected for analysis.

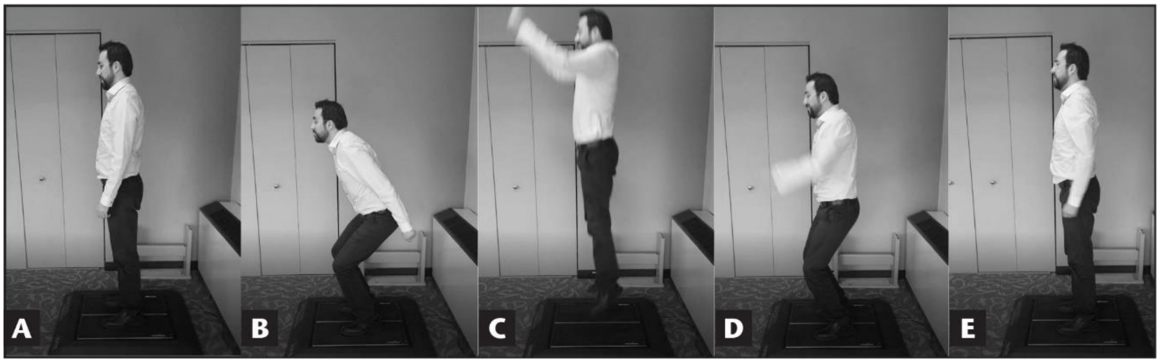


Figure 4. Sequence of A Countermovement Jump. (A) Before the jump, the participant stands in an upright position on the force platform as still as possible; (B) The participant squats as quickly as possible before the jump; (C) The participant jumps as high as possible; (D) The participant begins the smooth landing stage; and (E) The participant stands up straight and as still as possible.

Serial one- or two-legged jumps (hopping). Although this type of test measures force, velocity, and power, it is used to assess maximal jump force, which is correlated with bone strength, bone size, bone strength indices, total bone area, and tibial strength strain index (Hardcastle et al., 2014; Rantalainen et al., 2009; Runge & Hunter, 2006). Participants are instructed to hop on one forefoot or both forefeet with their knee almost straight and without touching the ground with their heel. Participants should hop 10 times. The software detects and eliminates hops if heels hit the ground; the hop with the highest force is used for analysis (Veilleux & Rauch, 2010).

Balance assessment/measurement of sway. This test can be used to assess balance, coordination, and fall-risk assessment in older adults. Participants try to stand as still as possible in a comfortable upright position with both arms hanging free and a foot on each side of the platform for a specific period of time (e.g., 10 seconds). Various feet positions and open or closed eyes, such as used by the Romberg, semi-tandem, and tandem stands, can be chosen to increase difficulty. Instructions for these foot positions are identical to the ones used in validated test batteries, such as the short physical performance battery (Guralnik et al., 1994). During these tests, the position of the center of pressure (COP) on the platform is recorded. In addition to the traditional scoring of these balance tests, outcome parameters (e.g., total COP path length [m], sway area [m2], mean velocity [m/s]) can be measured. These parameters can be used to describe the direction and extent of postural sway. The smaller the COP path length or sway area, the better the stability. The velocity (i.e., COP path length divided by trial duration) represents the amount of activity required to maintain stability; the smaller the COP velocity, the better the postural control (Treffel et al., 2016).

Safety of Muscle Mechanography

Muscle mechanography has been used in many research studies across various populations, including young and older adults (Buehring et al., 2015; Dietzel, Felsenberg, & Armbrecht, 2015; Hardcastle et al., 2014; Matheson et al., 2013; Rittweger et al., 2004; Runge et al., 2004; Siglinsky et al., 2015; Singh et al., 2014), athletes (including master athletes) (Ireland et al., 2015; Michaelis et al., 2008), as well as children and adolescents (Binkley & Specker, 2008; Fricke, Weidler, Tutlewski, & Schoenau, 2006; Veilleux & Rauch, 2010). None of these studies reported pain, falls, or fractures while using muscle mechanography. Furthermore, in the current authors' unpublished data of more than 300 older adults, all participants were able to complete most tests on the platform (<5% were not able to perform countermovement jumps). Mild joint pain was the only complaint, but there were no lasting adverse events.

Buehring et al. (2015) conducted a study to examine the safety of jumping mechanography (using countermovement jumps) in an older population including individuals with osteoporosis and prior vertebral fracture. Jumping mechanography was determined to be a safe and useful method. Self-reported pain did not change after countermovement jumps and no injuries or new vertebral fractures were sustained, even in individuals with low bone mass density and previous vertebral fractures (Buehring et al., 2015). Individuals older than 90 with moderate control of balance, who were unable to perform the repeated chair-rise test, were able to complete other tests, including countermovement jumps, without any complaints or adverse events (Rittweger et al., 2004). Very frail individuals may ask for more assistance to complete countermovement jumps and some may only be able to perform heel rises. Evidence supports the safety of muscle mechanography in older adults.

Reproducibility of Muscle Mechanography

The reproducibility of muscle mechanography has been examined in several studies (Fricke et al., 2006; Matheson et al., 2013; Rittweger et al., 2004; Veilleux & Rauch, 2010). Buehring et al. (2015) have recently found that jumping mechanography (i.e., using countermovement jumps) has excellent test–retest reliability compared to other traditional muscle function tests in 97 adults age 70 and older. Jumping mechanography and grip strength had the highest intraclass correlation coefficients (ICC) (0.93 and 0.95, respectively), whereas traditional chair rises and gait speeds had lower ICCs (0.81 and 0.76, respectively).

Other literature supports the finding that jumping mechanography and gait speed perform better than Timed Up and Go, 10-m gait speed, and chair-rise tests (Rittweger et al., 2004). Jumping mechanography has good test–retest reliability, with low intra-subject, short-term error (3.6%); large inter-subject coefficient of variation (45.4%); and a high test–retest correlation coefficient ($r = 0.99$) (Rittweger et al., 2004). Good reproducibility results of muscle mechanography are further supported in samples of children and middle-aged adults (Matheson et al., 2013; Veilleux & Rauch, 2010). Interrater coefficients of variation were <0.6% for the two-leg countermovement jumps and intrarater coefficients of variation were <5.3% for all variables (Matheson et al., 2013). Veilleux and Rauch (2010) reported coefficients of variation ranged from 3.4% to 7.5% for multiple one- and two-legged jumps, single two-legged jumps, and heel-rise tests.

Muscle mechanography is a method that has well-documented reliability, reproducibility, and promises to be a sensitive test to detect even small functional changes in older adults. In addition, it has less test variability than other traditional muscle function tests (e.g., gait speed, chair rise).

Implementing Muscle Mechanography in Nursing Research

Most nursing research studies involve the collection of data through traditional methods, such as self-reporting or observation tools. Using innovative and advanced methodology in nursing research is highly recommended (NINR, 2011). A growing body of evidence indicates that identifying muscle power, with specific attention to the contribution of force and velocity, is a critical component in the design of intervention strategies aimed at ameliorating muscle function and physical ability in older adults (Pojednic et al., 2012). Muscle mechanography provides in-depth knowledge of the individual contributions of force and velocity to muscle power so interventions can be tailored to optimize the most influential component. Muscle mechanography can also be used to evaluate the potential of nursing therapeutic interventions in older adults (Caserotti et al., 2001; Dietzel et al., 2015; Rantalainen et al., 2010; Runge et al., 2004; Singh et al., 2014; Tsubaki et al., 2016).

The current review highlights potential advantages of muscle mechanography, including (a) that it is computerized (making it less prone to human error and variation), (b) being able to report actual physical units of interest for particular tests, (c) assessing a wide range of physical ability (less ceiling or floor effects), and (d) that it is reproducible and safe in older adults. Muscle mechanography can assist nursing researchers toward building a comprehensive picture of the muscle function in older adults, predicting the onset of physical decline, and identifying the changes in muscle function parameters potentially more precisely than traditional methods (Buehring et al., 2015; Fricke et al., 2006; Matheson et al., 2013; Pojednic et al., 2012; Rittweger et al., 2004; Veilleux & Rauch, 2010). Because of these advantages, muscle mechanography has the potential to reduce the sample size, duration, and total cost of research studies.

Despite all these advantages, muscle mechanography has some limitations. First, although the method can be performed by most older adults, some may be unable to perform some tests due to severe frailty or significant physical impairments. However, even very frail older adults can perform at least one or two of the available tests. Second, studies are lacking to determine whether muscle mechanography results can be used to predict outcomes such as fractures, hospitalizations, and mortality. As researchers become familiar with muscle mechanography and begin incorporating this technology into more studies, data will be available to fill gaps in evidence. Muscle mechanography correlates well with measures of maximal force, such as grip strength and muscle mass, and also traditional muscle tests (Siglinsky et al., 2015). Many studies show that these muscle function parameters are associated with health outcomes among older adults. For example, muscle force correlates with bone health in older adults (Hardcastle et al., 2014; Rantalainen et al., 2009), and muscle power correlates with age (Buehring et al., 2010; Rantalainen et al., 2010; Runge et al., 2004), fall risk (Caserotti et al., 2001; Runge & Hunter, 2006; Runge et al., 2004), impaired physical performance and activities of daily living (Caserotti et al., 2001; Dietzel et al., 2015; Runge et al., 2004; Tsubaki et al., 2016), and sarcopenia (Siglinsky et al., 2015; Singh et al., 2014). As such, although no direct evidence exists that muscle mechanography can predict health outcomes, the correlation of muscle mechanography with traditional muscle function tests suggests that it could. Jumping mechanography has already been integrated into prospective studies and outcome results should be available in the next few years.

Conclusion

Muscle mechanography is an innovative and safe research tool for measuring muscle function in older adults that offers several advantages to currently used methods. Muscle mechanography is consistent with the movement toward an increased use of highly innovative technology to quantitatively measure health status and outcomes. More research is needed to examine whether muscle mechanography can predict health outcomes such as falls, fractures, loss of independence, hospitalizations, and mortality.

Chapter Summary

The first manuscript in this chapter introduced the phenomenon of sarcopenia in older adults. Gaps in knowledge were discussed and recommendations for future studies were addressed. The second manuscript in this chapter introduced muscle mechanography (MM) as a novel method that can be used to quantitatively assess muscle function parameters in older adults. The manuscript covered the mechanism of MM, the different types of tests, the parameters that can be obtained by using MM, and the measurement procedures. The safety and reproducibility of MM were also discussed.

CHAPTER 3

Chapter Introduction

The purpose of this study is threefold: 1) to describe the characteristics of muscle mass, strength, and function in older adults living in RCACs, 2) to determine, after controlling for pain, whether there is a difference in muscle mass, strength, and function among RCACs residents based on self-efficacy for exercise, depression, and social support levels, and 3) examine the convergent validity of MM with widely used traditional muscle function tests (i.e., SPPB, TUG, and grip strength). The overall goal of this study is to improve sarcopenia prevention research and practices, as well as to improve the physical function and delay LTC placement among RCACs residents.

Method

Research Design

This study is a secondary data analysis using a cross-sectional descriptive correlational design. The descriptive correlational design is intended to describe the association between the dependent and independent variables and provide information to generate future hypotheses and research. Data for this study were collected for a randomized, crossover design study that explored the effect of semi-recumbent vibration exercise on muscle mass, strength, and function in older adults. This study only included data collected at baseline prior to the intervention and control condition participation. Secondary data analysis is feasible as the data collection is usually time consuming and expensive. Secondary data analysis is also an effective way for new researchers with limited resources to begin to answer important research questions (Polit, & Beck, 2012). It is important to acknowledge that the available data set provides a unique access to vulnerable and understudied population.

The author of this study was the primary coordinator for the primary study. He was responsible for all aspects of study conduct such as recruiting, scheduling exercise sessions, supervising the interventions, and coordinating the assessment visits.

Research Questions and Hypotheses

The research questions that were addressed in this study include:

1) What are the self-efficacy for exercise, depression, and social support of older adults living in RCACs?
2) What are the muscle mass, strength, and function of older adults living in RCACs?

The hypotheses for this study include:

1) Participants with high self-efficacy for exercise will have greater muscle mass, strength, and function than those with low self-efficacy for exercise**.**
2) Participants without depressive symptoms will have greater muscle mass, strength, and function than those with depressive symptoms.
3) Participants with high social support will have greater muscle mass, strength, and function than those with low social support
4) Weight corrected jump power obtained by MM correlates well with other traditional muscle function and strength tests, including SPPB, TUG, and grip strength.

Sample and Setting

The participants of the original study were recruited from one RCAC located in a Midwestern city that was chosen by convenience. Inclusion criteria for research participants in the primary study included English-speaking older adults age 70 and older with no significant cognitive impairment. Participants were able to stand without assistance and free of any major illness such as end-stage organ disease. Excluded were older adults who could not speak English, had any injury or surgery in the last six months that limits ability to move around, or were not able to stand without assistance. The participants of the original study were recruited through flyers and community talks in the facility. The study coordinator explained the study to potential participants and answered their questions and concerns.

A total of 63 residents were solicited for participation in the primary study. Only 31 residents participated in the primary study. The entire sample of 31 participants were included in this secondary analysis. Many residents decided not to participate in the primary study. The most common reason residents declined to participate is that their schedule was already very busy and could not accommodate the exercise sessions. Other reasons include being not interested, having a deteriorated health status and frequent doctors' appointments, and providing care for an ill spouse. This study is underpowered, which will be discussed more thoroughly under Data Analysis Plan and Limitation Sections.

Instruments

This section of the paper provides a description of the tools that were used in the original study to measure the dependent and independent variables. The baseline measures of these variables before any intervention was started were use in this secondary analysis.

Dependent variables. The dependent variables measured in the primary study are muscle mass, muscle strength, and muscle function.

Muscle mass. A bioimpedance spectroscopy (ImpediMed SFB7) device was used to measure body composition including skeletal muscle mass. The device scans 256 frequencies between 4 kHz and 1000 kHz. The device utilizes Cole modelling with Hanai mixture theory to determine total body water (TBW), extracellular fluid (ECF) and intracellular fluid (ICF) from impedance data. Fat-free mass (FFM) and fat mass (FM) are then calculated on the device

(Yamada et al., 2013). Skeletal muscle mass (SM) was calculated using the equation developed by Janssen and colleagues where SM (kg) = [(height2 /R50 × 0.401) + (sex × 3.825) + (age × –0.071)] + 5.102. Height was measured in centimeters, R50 was measured in ohms between the right wrist and ankle in a supine position (men = 1 and women = 0), and age was measured in years (Janssen, Heymsfield, Baumgartner, & Ross, 2000).

Compared to the existing methods for assessing body composition (e.g., magnetic resonance imaging (MRI), computed tomography (CT), and dual-energy X-ray absorptiometry [DXA]), BIS is an affordable, noninvasive, easy-to-operate, and portable method for assessing lean mass in older adults (Yamada et al., 2013). BIS was found to be valid and reliable method to assess body compositions in young and older adults (Janssen et al., 2000; Sun et al., 2005; Yamada et al., 2013). Janssen and colleagues reported correlation coefficients between skeletal muscle mass determined by BIS and skeletal muscle mass measured by MRI exceeding 0.88 and standard errors of the estimate of 9% in a multiethnic sample of 158 women and 230 men (Janssen et al., 2000). In another study, body fat estimates by BIA (18.6 +/- 9.2 kg) was not significantly different from those obtained by DXA (18.2 +/- 7.9 kg). DXA showed a relatively good agreement with BIA [-0.39 +/- 3.3 (-6.9 to 6.1) kg] in all patients (Sun et al., 2005).

Muscle strength. Muscle strength is related to hand grip strength. The purpose of grip strength test is to measure the maximum isometric strength of the hand and forearm muscles. Grip strength was measured using a JAMAR® hand dynamometer, which is the “gold standard” for the measurement of grip strength (Mathiowetz, 2002). Each participant performed the test three times using participant’s non-dominant hand and the greatest score was selected for analysis.

Grip strength test has been widely used among older adults. Low grip strength is predictive of limited physical function, disability, longer hospitals stays, and mortality (Bohannon, 2015). Grip strength is inversely associated with all-cause mortality, cardiovascular mortality, non-cardiovascular mortality, myocardial infarction, stroke, fall, and fracture (Leong et al., 2015). Grip strength has an excellent inter-instrument reliability, intraclass correlation coefficients ranged from 0.90 to 0.97 (Mathiowetz, 2002). Another study examined the test–retest reliability of grip strength measured using a JAMAR® hand dynamometer over a 12-week period in older adults (Bohannon & Schaubert, 2005). Test and retest measurements did not differ significantly over time on either side. Intraclass correlation coefficients were 0.95 and 0.91 for the left and right hands, respectively (Bohannon & Schaubert, 2005).

Muscle function. Muscle function was measured by three tools: SPPB, MM, and TUG.

SPPB. The SPPB test is a feasible, useful, and commonly used tool to assess muscle function in older adults. SPPB test focuses primarily on lower extremity function and includes three components: a) a 4 meter walk at a usual pace to measure gait speed, b) one chair rise followed by 5 timed chair rises if the first is successfully completed, and c) balance stands with the feel held in different positions for 10 seconds each (Appendix B). The total score is range from 0 (worst performance) to 12 (best performance). Based on their SPPB scores, individuals can be classified with mobility limitations (0-9), or without mobility limitations (10-12) (Bernabeu-Mora et a., 2015; Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995).

The SPPB test has been widely used among older adults and is predictive of nursing home admission and mortality (Guralnik et al., 1994). A study showed that the test has a test-retest reliability of 0.87 (CI 95%: 0.77-0.96) in older adults aged 65 to 74 years (Gómez, Curcio, Alvarado, Zunzunegui, & Guralnik, 2013). Another study demonstrated evidence of validity and reliability of the SPPB in two very different populations (Freire, Guerra, Alvarado, Guralnik, &

Zunzunegui, 2012). The validity of the SPPB was demonstrated by the strong and consistent association with health status measures, in spite of the socioeconomic and cultural differences between the both groups. There was a graded decrease in mean SPPB scores with increasing limitation of lower limbs, disability, and poor health. Using the test–retest reliability the authors evaluated the intraclass correlation coefficient, which was high in both groups: 0.89 (95% CI: 0.83, 0.93) in the first group and 0.83 (95% CI: 0.73, 0.89) in the second group (Freire et al., 2012).

MM. MM is a tool that provides an objective quantification of the muscle function parameters of the lower limbs, including muscle power and force (Taani et al., 2017). Several tests can be performed through MM including the two-leg maximal countermovement jump. The countermovement jump was used to assess weight corrected jump power among the participants. This test has good test-retest reliability with low intrasubject short-term error (3.6%), large intersubject coefficient of variation (45.4%), and a high test-retest correlation coefficient (r=.99) (Rittweger, et al., 2004).

In a study by Buehring and colleagues, the countermovement jump test had excellent test–retest reliability compared to other traditional muscle function tests among older adults. The test had the highest intraclass correlation coefficients (ICC) (0.93), whereas traditional chair rises and gait speeds had lower ICCs (0.81 and 0.76, respectively) (Buehring et al., 2015). Detailed description of MM is provided in chapter 2 of this dissertation.

TUG. The TUG test includes the measurement of the time in seconds for an individual to rise from sitting from an armless chair, walk 3 meters, turn, walk back to the chair, and sit down (Appendix C). The test is a commonly used measure of functional mobility due to its requirement of performing multiple tasks such as standing up, walking, turning around 180 degrees, and sitting down (Podsiadlo & Richardson, 1991). The test is quick and easy to administer and requires no special equipment.

Although formal normal values are not available, a study found that older adults who completed the TUG test in less than 20 seconds were independent for basic transfers (e.g., tub and shower transfers) and ability of going outside alone while older adults who completed the test in more than 30 seconds tend to be much more dependent (e.g., need help with chair and toilet transfers, get in and out of the tub or shower) and were not able to go out alone (Podsiadlo & Richardson, 1991). The TUG test correlates with balance, gait speed, and functional capacity. The test also has a test-retest reliability of 0.99 (Podsiadlo & Richardson, 1991).

Independent variables. The independent variables measured in the primary study are self-efficacy for exercise, depression, social support, and pain.

Self-efficacy for exercise. Self-efficacy for exercise scale (SEE) was used to assess perceived self-efficacy and confidence to participate in exercise (Appendix D). The SEE scale was particularly designed for older adults and developed from a continuing care retirement community population (average age 85). The SEE scale is an 9-item scale with a possible range of scores of 0 to 90. For each item, the individual uses the scale from 0 (Not Confident) to 10 (Very Confident) to describe his/her current confidence that he/she could exercise 3 times a week for 20 minutes each time (Resnick & Jenkins, 2000). Total score is calculated by summing the responses to each question. A higher score indicates higher self-efficacy for exercise.

Prior use of the SEE scale in older adults living in a continuing care retirement community provided evidence of reliability and validity (Resnick & Jenkins, 2000). The scale demonstrated internal consistency with an alpha coefficient of 0.92 and validity by finding a significant correlation between scores on the SEE and exercise behavior ($r = 0.56$, $P < .05$)

(Resnick & Jenkins, 2000).

Depression. Depression was measured using the short form of the Geriatric Depression Scale (GDS) (Appendix E). Although there are many tools available to assess for depression, the GDS was designed specifically for older adults and its items were developed after careful consideration of unique characteristics of depression in older adults (Sheikh & Yesavage, 1986). The scale assesses the symptoms of diminishing interest in activities, diminishing in social activities, life satisfaction, feeling of worthlessness, cognitive impairment, and suicidality (Sheikh & Yesavage, 1986). The short form of the GDS is more easily used by physically ill and mildly to moderately demented patients who have short attention spans and/or feel easily fatigued. The short form of the GDS is a self-report scale consists of 15 yes/no questions. Each question is scored as either 0 or 1 points depending upon whether the item is worded positively or negatively (Sheikh & Yesavage, 1986). Of the 15 items, 10 items indicate the presence of depression when answered positively, while the rest of the items (1,5,7,11,13) indicate depression when answered negatively. A score > 5 points is suggestive of depression and a score ≥ 10 points is almost always indicative of depression. The GDS was found to have Crohnbach's alpha of 0.94, and a 92% sensitivity and an 89% specificity when evaluated against diagnostic criteria (Allen & Annells, 2009; Marc, Raue, & Bruce, 2008).

Social support. Social support was measured by the abbreviated version of the Lubben Social Network Scale (LSNS-6) (Appendix F). The LSNS-6 is a six-item, self-reported scale to assess social isolation in older adults aged 65 years and older by measuring perceived social support received by family and friends (Lubben et al., 2006). The LSNS-6 assesses the size, closeness, and frequency of contacts of a respondent's social network including both kin/family and nonrelated individuals. The LSNS-6 consists of two subscales: Family subscale which consists of three times that ask about relatives and Friends subscale which consists of three times that ask about friends. The total scale score is the sum of the six items and ranges from 0 to 30, where high scores indicate good informal social support. Individuals scoring < 12 indicate a positive screen for social isolation and should be considered candidates for additional assessment and referral (Lubben et al., 2006). Participants screening positive on the LSNS-6 are considered socially isolated. Scores of less than 6 on the three-item LSNS-6 Family subscale are considered to have marginal family ties and those with scores of less than 6 on the three-item LSNS-6 Friends subscale to have marginal friendship ties.

Low scores have been correlated with physical health problems (Mor-Borak, Miller, & Syme 1991), all-cause hospitalization (Mistry, Rosansky, McQuire, McDermott, & Jarvik, 2001), depression (Dorfman et al., 1995), lack of adherence to good health practices (Potts, Hurwicz, Goldstein, & Berkanovic, 1992), and mortality (Ceria et al., 2001). LSNS-6 is a reliable and valid tool for the measurement of social support. Crohnbach's alpha for the subscales ranges from 0.80 to 0.89 (Lubben et al., 2006).

Pain. Pain was assessed by the Numeric Rating Scale (NRS), which is a useful tool to assess pain in individuals who can point to or state the number that reflects their current pain level (Appendix G). The NRS is a widely-used scale to assess pain among cognitively intact young and older adults (Herr, Spratt, Mobily, & Richardson, 2004). The NRS is an 11-point scale from 0 to 10 (0 = no pain, 1-3 = mild pain, 4-6 = moderate pain, 7-10 = sever pain). Individuals verbally select a value that is most in line with the intensity of pain that they have experienced in the last 24 hours.

The NRS has adequate test-retest reliability for a single pair of assessments (one assessment during week 1, one assessment during week 2) (r = 0.63) and good test-retest reliability for ratings on 2 or more days during week 1 compared to 2 or more days during week 2 (r = 0.79 – 0.92) (Jensen & McFarland, 1993). The scale also has excellent interrater reliability with 100% agreement between two raters and good internal consistency in participants aged 65 to 94 years (Cronbach's alpha = 0.87) (Herr et al, 2004). The NPR has good sensitivity while producing data that can be statistically analyzed (Williamson & Hoggar, 2005)

Other variables. Additional variables were measured to describe the sample, including age, sex, and body mass index (BMI). Weight (in kilograms) and height (in centimeters) were measured. BMI was calculated by using the formula, weight in kilograms divided by the square of the height in meters. To assess the number of falls in the last year and the number of fractures after age 50, the following questions were used: "How many times have you fallen in the last year?" and "Have you ever broken a bone over age 50? If yes, how many times?"

Research Procedures

This section describes the data collection procedures conducted in the primary study. All potential subjects were scheduled for a screening visit to collect information about eligibility. An appointment was made to do the assessment session at the facility. Three subjects did not meet the eligible criteria. One subject had a recent hip surgery, one subject had a back surgery, and one subject had a severe end organ disease. All the collected information from these three subjects who did not meet the inclusion criteria to participate was destroyed. Participants were provided with a reminder call within 24 hours of the scheduled data collection session. In the data collection session, the study questionnaires (SEE, GDS, LSNS, and NRS) were administered and MM, BIS, SPPB, TUG, and grip strength tests were performed. The purpose of each tool was explained to the participant.

Two strategies were used to reduce participant burden and potentially limit missing data:

1) the data collectors administered the tools by interview; and 2) the participants were asked if they are fatigued and want to finish the questionnaires or muscle function tests after a break. In addition, participants were familiarized and instructed on the correct method to perform the muscle function tests. All tests were demonstrated by the data collectors before the participants performed any of the tests. Two data collectors were presented during performance of all muscle function tests and all participants wore a gait belt to enhance safety. Testing was done in a private and quiet location at the facility. The research team met regularly to assure that all recruitment, consent, and data collection and measurement procedures were met.

Data Analysis Plan

After gaining access to the de-identified data, all data were entered into a password protected database. Cases with missing data were included in the analysis where they had complete data. Statistical analysis was performed using Statistical Package for Social Sciences software (version 21, SPSS, Inc, Chicago, IL, USA). The study is underpowered due to the small sample size. Therefore, descriptive analysis is reported. The descriptive results provide new information about a vulnerable and difficult to access population. The findings provided information regarding effect sizes between the independent and dependent variables. Inferential analyses were performed with acknowledgement of the potential for Type II error. The data analysis plan is documented in Appendix I.

Descriptive statistics of frequencies, means, standard deviations and ranges were used to describe the sample and answer questions 1 and 2 (Appendix I). Assumptions for statistical tests were examined. The distributions of all continuous variables were examined for skewness and the skewness calculations showed no skewness. The correlation coefficient values between pain and the dependent variables (i.e., muscle mass, strength, and function) indicated that pain was not a significant factor. After eliminating the covariate (pain), multiple t-tests were carried out to answer the first three hypotheses (1, 2, and 3). T-test was used to determine the association between the independent variables (i.e., self-efficacy for exercise, depression, and social support) and dependent variables (i.e., muscle mass, strength, and function). Pearson's product moment correlation coefficient values between traditional muscle function tests (i.e., gait speed, grip strength, chair rise, SPPB, and TUG) and muscle power were reported to describe the convergent validity of MM with other traditional muscle function tests (Hypothesis 4).

Strengths and Limitations

This study has several strengths. First, the results of this study contributed to the body of knowledge on sarcopenia and its cognitive and psychosocial risk factors among vulnerable and understudied population. Second, using sophisticated equipment to measure the outcome variables provided precise measurements of muscle mass, strength, and function. Third, the study allowed to examine the convergent validity of MM with widely used traditional muscle function tests. However, this study has several limitations. A descriptive, correlational design is limited in the results that can be reported and causality cannot be inferred. Only strength of relationships between variables was reported. The small sample size was another limitation, which limits generalizability. This is due to the fact that this analysis was secondary in nature and the sample size was predetermined. However, the results were used to gain more information on effect sizes between the independent and dependent variables. The small sample size and inferential analyses planned may lead to a Type II error. Moreover, the original study recruited participants from one facility as well as individuals with end-stage organ disease, cognitive impairment, recent injury or surgery that limits ability to move around, and who were unable to stand without assistance were excluded. These limitations produce a homogenous sample and limit generalizability to a broader population. Thus, findings will need to be viewed with caution.

Measurement error can be a significant threat to the internal validity of this study. The SPPB and TUG tests have limitations including that older adults who have very low functional ability may not be able to perform these tests. Other limitations of these tests include dichotomous (yes/no) determinations and being prone to human errors as the final results depend on the times taken by individual examiners. Although BIA is inexpensive, noninvasive, and well correlate with MRI and DXA predictions, the use of BIA to assess muscle mass presents a drawback because the dehydration problem that can be observed in older adults. Dehydration causes an increase in the body's electrical resistance, which may result in an underestimation of fat-free mass and an overestimation of body fat. A significant limitation in this study was that all the potential confounding variables could not be controlled for, which may affect the results. Finally, although self-efficacy, depression, and social support were measured using validated scoring systems, the scores may not be robust due to only one time measurement. Future longitudinal studies, including large-scale cohort studies, and repeated measures are necessary and would improve accuracy by providing more robust findings.

Chapter Summary

The goal of this cross-sectional descriptive correlation study was to fill the gaps that currently exist in the literature about the relationship between self-efficacy for exercise, depression, and social support and sarcopenia in older adults. The study also examined the convergent validity of MM with widely used traditional muscle function tests (i.e., SPPB, TUG, and grip strength). This chapter provided an overview of the sample, procedures used in the primary study for data collection, and the instruments and data analysis methods used in this study. Finally, this chapter discussed the limitations of this study.

CHAPTER 4

Chapter Introduction

In this chapter the study design, setting, and sample are described. The measurement methods and statistical analysis procedures used are described, and the study results are discussed. Characteristics of self-efficacy for exercise, depression, social support, muscle outcomes including muscle mass, strength, and function are reported and discussed. The findings on the associations between these variables, as well as the convergent validity of MM are discussed. Finally, limitations and potential implication of the study findings are addressed.

Introduction

Sarcopenia is a geriatric syndrome characterized by a reduction in muscle mass, strength, and function in older adults (Cruz-Jentoft et al., 2010). This reduction leads to negative outcomes including reduced mobility and independence, falls, and fractures (Bruyère et al., 2016). Sarcopenia also increases usage of long-term care facilities and nursing homes, hospitalization, morbidity, and mortality, which places a burden on individual, family, and healthcare system (Bruyère et al., 2016; Clark & Manini, 2010; Hirani et al., 2015; Janssen, 2010). Estimates indicate that sarcopenia costs the U.S. healthcare system around $18.5 billion annually (Janssen, et al., 2004).

The etiology of sarcopenia is multifactorial, consisting of hormonal changes, endocrine issues, protein synthesis, proteolysis, inflammatory processes, physical inactivity and malnutrition (Fielding et al., 2011; Henwood et al., 2014). While these mechanisms and their role on the onset and progression of sarcopenia are well understood, other factors including cognitive and psychosocial factors are poorly understood. For example, physical activity and exercise have shown promises in preventing sarcopenia and improving physical function (Cruz-

Jentoft et al., 2014; Kamel, 2003; Morley, 2012). People who are physically inactive or lead a sedentary lifestyle are less likely to stimulate the muscle regeneration process, making them more susceptible to developing sarcopenia (Gianoudis et al., 2014; Morley, 2012). Only 51.1% and 21.9% of older adults meet the recommended aerobic and resistance-training guidelines, respectively (Brady & Straight, 2014). It is crucial to explore which factors might underlie any effects of physical activity and exercise on physical function and muscle outcomes. Self-efficacy is a major predictor of physical activity and exercise among older adults as it can enhance or impede the motivation to exercise and be active (Goisser et al., 2015; McAuley et al., 2011). However, the influence of self-efficacy is one of the major aspect that is rarely addressed so far in sarcopenia research (Brady et al., 2014; Goisser et al., 2015), and yet no studies have been conducted to addressed the association between self-efficacy and sarcopenia.

Sarcopenia and depression seem to share several common risk factors, such as physical inactivity, malnutrition, hormonal dysregulation, and upregulation of inflammatory markers such as cytokines (Bauer et al., 2013; Beaudart et al., 2014; Cruz-Jenoft et al., 2010; Fiske et al., 2009; Morley et al., 2010; Muir & Montero-Odasso, 2011). However, recent studies showed inconsistent results about the association between sarcopenia and depression. Hsu and colleagues found that sarcopenia was associated with depressive symptoms (Hsu et al., 2014), whereas Byeon and colleagues reported no association between depression and sarcopenia among older adults (Byeon et al., 2016). Social support and sarcopenia also appear to share common risk factors. Social support impacts the relationship between self-efficacy and self-management behaviors and predicts the physical health in older adults (Gallant, 2003). While older adults who have strong social support are less likely to lead inactive lifestyles and be depressed, individuals with poor social support are prone to be isolated, depressed, and inactive (Wallace et al., 2015;

Yeom et al., 2008). These outcomes negatively impact the physical function in older adults. More research is needed to further examine the association between social support and sarcopenia. A greater understanding of the factors contributing to sarcopenia is crucial to prevent sarcopenia and design intervention to decrease its potential consequences.

In addition, it is suggested that the lack of appropriate assessment and treatment is a critical factor for increased physical impairments (Giuliani et al., 2008; Roberts et al., 2013). Many traditional methodologies exist to assess muscle function; however, all have important limitations. These limitations include yes/no determinations (e.g., balance test) and floor effect (e.g., chair rise test has). The traditional tests are also prone to tester subjectivity as the results depend on the time taken by individual examiners (e.g. SPPB, gait speed, TUG) (Buehring et al., 2010; Taani et al., 2017). Thus, performing more sophisticated assessment of muscle function is needed to identify limitations, understand the predictive value of specific impairments, and target intervention modalities (Giuliani et al., 2008; Guralnik et al., 1994; Taani et al., 2017).

Muscle Mechanography (MM) is a promising tool for assessing muscle function and obtaining benchmarks for functional data (Taani et al., 2017). MM provides an objective quantification of muscle function parameters including muscle power and force by using maximal countermovement jumps, serial hopping, or heel raises performed on a ground reaction force platform. However, data comparing MM with traditional muscle function tests is limited and further research is needed to validate MM with other commonly used muscle function tests (Buehring et al., 2015; Rittweger et al., 2004; Siglinsky et al., 2015).

This study aimed to describe the self-efficacy for exercise, depression, and social support of the participants as well as their muscle characteristics including muscle mass, strength, and function. In addition, four hypotheses were tested:

1) Participants with high self-efficacy for exercise will have greater muscle mass, strength, and function than those with low self-efficacy for exercise.
2) Participants without depressive symptoms will have greater muscle mass, strength, and function than those with depressive symptoms.
3) Participants with high social support will have greater muscle mass, strength, and function than those with low social support.
4) Weight corrected jump power obtained by MM correlates well with other traditional muscle function and strength tests, including SPPB, TUG, and grip strength.

Methods

Study Design

This is a secondary data analysis using data collected for a randomized crossover design study to investigate the effectiveness of semi-recumbent vibration exercise on muscle mass, strength, and function in older adults. The study consisted of several visits; screening and baseline visit followed by eight weeks of training three times a week, visit at eight weeks followed by four weeks of washout, visit at 12 weeks followed by eight weeks of training three times a week, and a final visit at 20 weeks. Each participant signed an IRB-approved, protocol-specific informed consent in accordance with the IRB of University of Wisconsin Madison.

At the screening visit, participants were asked information about their medical history including fractures and falls within the last 12 months. At the baseline visit several questionnaires were obtained and participants then were proceeded with muscle function tests (SPPB, grip strength, TUG, and MM). Participants were then randomized into one of two groups, the first group received vibration treatment for the first eight weeks and the second group received sham treatment. After eight weeks both groups have gone through a 4-week wash-out period and then crossover occurred. The participants were trained for 10 minutes, three times a week, during the active 16 total weeks.

Study Sample

In the primary study, 31 older adults were recruited from a Residential Care Apartment Complex (RACA) located in the Midwestern United States. Study eligibility requirements included English-speaking older adults age 70 and older with no significant cognitive impairment. Participants were able to stand without assistance and free of any major illness such as end-stage organ disease. Excluded were older adults who could not speak English, those had any injury or surgery in the last six months that limits ability to move around, or those who were not able to stand without assistance. The entire sample of 31 participants were included in this secondary analysis and only baseline data collected from the participants were used.

Measures

Demographic data were obtained such as age, sex, and BMI. Weight (in kilograms) and height (in centimeters) were measured. The formula used to calculate BMI is weight (Kg)/height (cm^2) (Jensen et al., 2013). To assess the number of falls and the number of fractures after age 50, the following questions were used: “How many times have you fallen in the last year?” and “Have you ever broken a bone over age 50? If yes, how many times?”

Self-efficacy for exercise. The Self-Efficacy for Exercise Scale (SEE) was used to assess participants' confidence in their ability to continue exercising despite barriers to exercise (Resnick & Jenkins, 2000). The SEE scale is an 9-item scale with a possible range of scores of 0 to 90. The score of each item ranges from 0 (“not confident”) to 10 (“very confident”), with lower values indicating lower self-efficacy. The reliability, validity, and internal consistency (Cronbach $\alpha = 0.92$) of the scale have been established (Resnick & Jenkins, 2000).

Depression. The short form of the Geriatric Depression Scale (GDS-15) was used to measure the depressive symptoms (Sheikh & Yesavage, 1986). The GDS-15 includes 15 yes/no questions with one point for each depressive symptom. The total score ranges from 0 to 15, with 15 being most depressed. A cut-off point of > 5 points can be considered as indicating depression. The scale was found to have Crohnbach's alpha of 0.94, and a 92% sensitivity and an 89% specificity when evaluated against diagnostic criteria (Allen & Annells, 2009; Marc et al., 2008).

Social support. The abbreviated version of the Lubben Social Network Scale (LSNS-6) was used to measure perceived social support received by family and friends (Lubben et al., 2006). The scale consists of 6 items and it has two subscales: family and friends. The total score ranges from 0 to 30, higher scores indicating greater social support. Individuals scoring ≤ 11 indicate a positive screen for social isolation and should be considered candidates for additional assessment and referral (Lubben et al., 2006). Participants screening positive are considered socially isolated. Crohnbach's alpha for the subscales ranges from 0.84 to 0.89 (Lubben et al., 2006).

Pain. The Numeric Rating Scale (NRS) was used to assess the pain level. The NRS is an 11-point scale from 0 to 10 (0 = no pain, 1-3 = mild pain, 4-6 = moderate pain, 7-10 = sever pain). The scale is a useful tool to assess pain in those who can state the number that reflects their current pain level and widely-used among older adults (Herr et al., 2004). The NRS has good test-retest reliability for ratings on 2 or more days during week 1 compared to 2 or more days during week 2 (r = 0.79 – 0.92) (Jensen & McFarland, 1993). It has also excellent interrater reliability with 100% agreement between two raters and good internal consistency in participants aged 65 to 94 years (Cronbach's alpha = 0.87) (Herr et al, 2004).

Skeletal muscle mass. A bioimpedance spectroscopy (ImpediMed SFB7) device was used to measure body composition. The details of BIS have previously been described (Kaysen et al., 2005; Gudivaka, Schoeller, Spiegel, & Kushner, 1994). Skeletal muscle mass (SM) was calculated using the equation developed by Janssen and colleagues where SM (kg) = [(height2 /R50 × 0.401) + (sex × 3.825) + (age × –0.071)] + 5.102. Height was measured in centimeters, R50 was measured in ohms between the right wrist and ankle in a supine position, and age was measured in years (Janssen et al., 2000). Compared to the existing methods (e.g., MRI and DXA), BIS is a feasible, noninvasive, and portable tool for assessing body composition (Yamada et al., 2013).

Muscle strength-hand grip. This was measured using a JAMAR® handgrip dynamometer, which is the "gold standard" for the measurement of grip strength (Mathiowetz, 2002). Subjects used their dominant hand unless otherwise instructed. Three measurements were taken and the highest score was recorded.

Muscle function. Muscle function was measured by three tools: SPPB, MM, and TUG. SPPB test includes measures of standing balance (timing of tandem, semitandem, and side-by-side stands), gait speed (4-m walking speed), and ability and the time needed to rise from a chair five times (Guralnik et al., 1994). Each component has a possible score of 0–4 and the total SPPB scores ranges from 0–12. Individuals can be classified with low performance (0-6), intermediate performance (7-9), and high performance (10-12) (Guralnik et al., 2000). TUG test includes the measurement of the time in seconds for an individual to rise from sitting from an armless chair, walk three meters, turn and walk back to the chair, and sit down. The test has a test-retest reliability of 0.99 (Podsiadlo & Richardson, 1991).

MM provides an objective quantification of muscle function parameters of the lower limbs, including muscle power (i.e., weight corrected jump power). The details of MM have previously been described (Taani et al., 2017). Several tests can be performed by MM including the two-leg maximal countermovement jump. Three jumps were performed on a force plate (Leonardo, Novotec, Pforzheim, Germany) by each participant and the jump with the greatest peak power was recorded. This test has good test-retest reliability with low intrasubject short-term error (3.6%), large intersubject coefficient of variation (45.4%), and a high test-retest correlation coefficient (r=.99) (Rittweger et al., 2004).

Statistical Analysis

SPSS® version 21 was used for data analysis. Assumptions for statistical tests were examined. None of the continuous variables were skewed. Descriptive statistics were used to describe the self-efficacy for exercise, depression, social support, and muscle outcomes including muscle mass, strength, and function. Pain was tested for possible inclusion as a covariate but was not significantly related to the dependent variables. T-tests for independent samples were conducted to determine whether there is a difference in muscle outcomes (i.e., muscle mass, strength, and function) based on self-efficacy for exercise, depression, and social support (Hypothesis 1,2, and 3). Self-efficacy for exercise, depression, and social support variables were grouped by sample mean for self-efficacy and established cut-off points for depression and social support. Pearson's product moment correlation coefficients were used to examine the association of muscle function tests (i.e., gait speed, grip strength, chair rise, SPPB, and TUG) with weight corrected jump power obtained by MM (Hypothesis 4). This study is underpowered as the sample size was predetermined. The study focused on descriptive analyses, which provided new information on a vulnerable and difficult to access population. Inferential analyses were performed with acknowledgement of the potential for Type II error.

Results

Sample Characteristics

Thirty-one participants were included in the analysis. Participants' ages ranged from 75 to 99 with a mean of 88 years (*SD* = 6). Participants were predominately female *(n*= 21, 71 %), which is consistent with this population. Participants BMI ranged from 18.86 to 41.99 with a mean of 27.7 kg/m^2 (*SD* = 5.12). Forty-one percent (n=9) of the sample had an incidence of fall in the past year. Five subjects reported more than one fall in the past year (16.2%) and 8 subjects reported only one fall in the past year (25.8%). Twelve subjects reported a broken bone over age 50 years (38.7%). Only one subject reported three broken bones after age 50 years (3.2%), 5 subjects reported two broken bones after age 50 years (16.2%), and 6 subjects reported only one broken bone after age 50 years (19.4%). These results are displayed in Table 2.

Table 2
Demographic Characteristics of Sample (n = 31)

Characteristic	*M*	*SD*	Range
Age in years	88	6	75-99
Body mass index (kg/m^2)	27.70	5.12	18.86-41.99
Characteristic	***n***	***%***	
Gender			
Male	9	29	
Female	22	71	
Fall			
Yes	13	41.9	
No	18	58.1	
Number of falls			
1	8	25.8	
More than 1	5	16.2	
Broken bone			
Yes	12	38.7	
No	19	61.3	

Number of broken bone		
1	6	19.4
2	5	16.2
3	1	3.2

Note: Fall: Incidence of fall in the past year, Number of falls: Number of falls in the past year, Broken bones: Broken bones after age 50, Number of broken: Number of broken bone after age 50.

Description of Self-efficacy, Depression, and Social Support

The SEE was used to measure self-efficacy for exercise. The SEE scores ranged from 3 to 89 with a mean of 50 (*SD* = 26.04). The GDS was used to screen for depression. Based on the established cut-off points, subjects who scored greater than 5 were classified as depressed and those who scored less than or equal 5 were classified as not depressed. The GDS scores ranged from 0 to 13 with a mean of 2.97 (*SD* = 2.79). Only four (12.9%) individuals were depressed. The LSNS results were categorized based on the established cut-off points as socially isolated (≤ 11) and not socially isolated (> 11). The LSNS scores ranged from 2 to 25 with a mean of 14.71 (*SD* = 6.98). Ten individuals were categorized as socially isolated (32.3%). These results are described in Table 3.

Table 3
Description of Self-efficacy, Depression, and Social Support (n = 31)

Classification	*M*	*SD*	Range	*n*	%
SEE	50	26.04	3 to 89	31	
GDS	2.97	2.79	0 to 13		
Not depressed				27	87.1
Depressed				4	12.9
LSNS	14.71	6.98	2 to 25		
Not socially isolated				21	67.7
Socially isolated				10	32.3

Note: SEE: Self-Efficacy for Exercise Scale, GDS: Geriatric Depression Scale-15, LSNS: Lubben Social Network Scale-6.

Description of Muscle Mass and Strength

Skeletal muscle mass (SM) was measured using BIS. The mean score of SM was 17.51 kg (*SD* = 5.28). Muscle strength was measured by the grip strength (GS) test. The mean score of GS was 14 kg (*SD* = 5.91) (Table 4). There was a significant difference in the mean score of SM between men and women. The mean score of SM for men was 22.27 kg (*SD* = 6.9) and 15.56 kg for women (*SD* = 2.84); $t(29) = 3.9$, $p = .001$. There was also a significant difference in the mean score of GS between men (*M* = 21.78 kg, *SD* = 4.32) and women (*M* = 10.82 kg, *SD* = 2.50); $t(29) = 8.901$, $p < .001$. The results showed that men had greater SM and GS than women (Table 5).

Table 4
Description of Muscle Mass and Strength (n = 31)

Classification	*M*	*SD*
SM	17.51	5.28
GS	14.00	5.91

Note: SM: Total Skeletal Muscle Mass (kg), GS: Grip Strength (kg).

Table 5
Differences in Muscle Mass and Strength Based on Gender (n = 31)

	Male		Female			
	M	*SD*	*M*	*SD*	*t*	*p*
SM	22.27	6.9	15.56	2.84	3.9*	=.001*
GS	21.78	4.32	10.82	2.5	8.901*	<.001*

*$p < .05$
Note: SM: Total Skeletal Muscle Mass (kg), GS: Grip Strength (kg).

Description of Muscle Function

Gait speed, repeated chair rise, SPPB, TUG and weight corrected jump power were used to assess muscle function. Mean score of 4-m gait speed was 0.65 m/s (*SD* = 0.18), repeated chair rise was 17.28 s (*SD* = 5.83), SPPB was 6.35 (*SD* = 2.69), TUG was 18.31 s (*SD* = 7.58), and weight corrected jump power was 8.56 W/kg (*SD* = 5.51). Based on the established cut-off points for gait speed by the European Working Group on Sarcopenia in Older People (EWGSOP) (Cruz-Jentoft et al., 2010); 24 (77.4%) individuals had slow gait speed. Based on the established cut-off points for SPPB (Guralnik et al., 2000), 18 (58.1%) individuals had low SPPB performance and 8 (25.8%) had intermediate SPPB performance. Only 5 (16.1%) individuals had high performance. The results are detailed in Table 6.

Men generated significantly higher weight corrected jump power than women. The mean score of weight corrected jump power for men was 12.06 w/kg (*SD* = 5.97) and 7.29 w/kg for women (*SD* = 4.87); $t(28) = 2.234$, $p = .034$. Men had numerically higher mean measurements than women for gait speed 0.67 (*SD* = 0.18) vs. 0.65 (*SD* = 0.18) m/s. Men also performed better than women on repeated chair rise 15.5 (*SD* = 6.43) vs. 17.9 (*SD* = 5.69) s and TUG 15.82 (*SD* = 5.95) vs. 19.21 (*SD* = 8.01) s. Women had greater mean of SPPB score 6.36 (*SD* = 2.48) than men 6.33 (*SD* = 3.32). However, these differences were not statistically significant (Table 7).

Table 6
Description of Muscle Function

Classification	*M*	*SD*	*n*	%
Chair rise	17.28	5.83	24	
TUG	18.31	7.58	31	
Weight corrected jump power	8.56	5.51	30	
Gait speed	0.65	0.18	31	
≤ 0.8 m/s			24	77.4
> 0.8 m/s			7	22.6
SPPB	6.35	2.69	31	
0-6			18	58.1
7-9			8	25.8
10-12			5	16.1

Note: Chair rise and Timed Up and Go (TUG) are measured by second (s), Weight corrected jump power is measured by Watt/kg, Gait speed is measured by meter/second (m/s), Gait speed score > 0.8 m/s = slow gait speed, Gait speed score ≤ 0.8 m/s = fast gait speed, SPPB: Short Physical Performance Battery.

Table 7
Differences in Muscle Function Based on Gender

	Males (*n*=8)		Females (*n=22)*			
	M	*SD*	*M*	*SD*	*t*	*p*
Gait speed	0.67	0.18	0.65	0.18	.292	.772
Chair rise**	15.5	6.43	17.9	5.69	.868	.395
SPPB	6.33	3.32	6.36	2.48	.028	.978
TUG	15.82	5.95	19.21	8.01	1.089	.286
Weight corrected jump power***	12.06	5.97	7.29	4.87	2.234	.034*

*p< .05, **n=24, ***n=30
Note: Gait speed is measured by meter/second (m/s), Chair rise and Timed Up and Go (TUG) are measured by second (s), SPPB: Short Physical Performance Battery, Weight corrected jump power is measured by Watt/kg.

Relationship Between Muscle Outcomes and Self-Efficacy, Depression, and Social Support

Self-efficacy for exercise, depression, and social support were dichotomized. Groups were created for self-efficacy based on the mean score. Depression and social support were grouped based on the established cut-off points (Allen & Annells, 2009; Marc et al., 2008; Lubben et al., 2006). The SM, GS, gait speed, repeated chair rise, SPPB, TUG, and jump power were examined as continues variables. T-tests were performed to examine the differences in muscle outcomes (i.e., SM, GS, gait speed, repeated chair rise, SPPB, TUG, jump power) based on self-efficacy, depression, and social support. No significant differences were found in muscle outcomes based on self-efficacy (Table 8) and social support (Table 10). There was a significant difference in chair rise time based on depression ($t(22) = 2.597$, p = .016). Subjects without depressive symptoms completed the five repeated chair rises faster than subjects with depressive symptoms. The mean score for subjects without depressive symptoms was 16.45 (SD = 5.34) and for subjects with depressive symptoms was 26.45 (SD = 0.47) (Table 9).

Table 8
Differences in Muscle Outcomes Based on the Self-Efficacy

	High self-efficacy		Low self-efficacy			
	M	*SD*	*M*	*SD*	*t*	*p*
SM	18.10	5.13	16.87	5.55	.639	.528
GS	14.94	5.91	13.00	5.94	.909	.371
Gait speed	0.69	0.18	0.61	0.17	1.303	.203
Chair rise*	15.70	5.88	19.49	5.26	1.623	.119
SPPB	6.5	2.89	5.93	2.49	.841	.407
TUG	17.35	5.43	19.39	9.57	.730	.471
Weight corrected jump power**	9.90	5.87	7.22	4.97	1.35	.188

N=31, *n=24, **n=30
Note: SM: Total Skeletal Muscle Mass (kg), GS: Grip Strength (kg), Gait speed is measured by meter/second (m/s), Chair rise and Timed Up and Go (TUG) are measured by second (s); SPPB: Short Physical Performance Battery, Weight corrected jump power power is measured by Watt/kg.

Table 9
Differences in Muscle Outcomes Based on Depressive Symptoms

	Not depressed		Depressed			
	M	*SD*	*M*	*SD*	*t*	*p*
SM	19.22	2.50	17.25	5.56	.689	.496
GS	14.19	6.00	12.75	5.91	.447	.658
Gait speed	0.67	0.18	0.53	0.10	1.460	.155
Chair rise**	16.45	5.34	26.45	0.47	2.597	.016*
SPPB	6.56	2.79	5.00	1.41	1.082	.288
TUG	17.59	7.74	22.98	4.63	1.343	.190
Weight corrected jump power***	8.86	5.70	6.61	4.16	.755	.456

*p< .05, N=31, **n=24, ***n=30
Note: SM: Total Skeletal Muscle Mass (kg), GS: Grip Strength (kg), Gait speed is measured by meter/second (m/s), Chair rise and Timed Up and Go (TUG) are measured by second (s); SPPB: Short Physical Performance Battery, Weight corrected jump power is measured by Watt/kg..

Table 10
Differences in Muscle Outcomes Based on Social Support

	Not socially isolated		Socially isolated			
	M	*SD*	*M*	*SD*	*t*	*p*
SM	18.42	5.20	15.60	5.22	1.415	.168
GS	14.33	6.53	13.30	4.57	.449	.657
Gait speed	0.7	0.20	0.63	0.17	1.055	.300
Chair rise*	16.60	5.44	17.70	6.20	.442	.663
SPPB	7.0	2.63	6.05	2.73	.919	.366
TUG	19.00	8.24	16.92	6.18	.703	.488
Weight corrected jump power**	9.89	4.30	7.90	6.02	1.044	.307

N=31, *n=24, **n=30

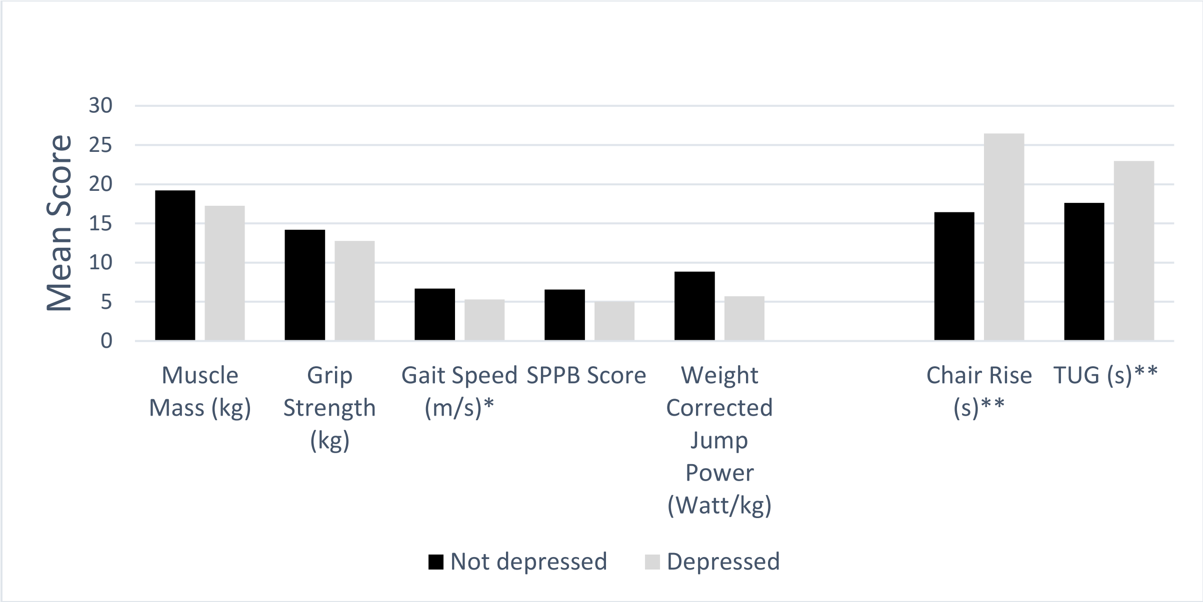
Note: SM: Total Skeletal Muscle Mass (kg), GS: Grip Strength (kg), Gait speed is measured by meter/second (m/s), Chair rise and Timed Up and Go (TUG) are measured by second (s); SPPB: Short Physical Performance Battery, Weight corrected jump power is measured by Watt/kg.

Graphical Presentation of the Differences

Figure 5 graphically presents the mean scores of muscle mass, strength, and function based on the dichotomized groups of self-efficacy, depression, and social support. The figure suggests that there is a trend for subjects with higher self-efficacy scoring better on all measurements than the subjects with lower self-efficacy (Figure 5-A). There is also a trend for subjects without depressive symptoms scoring better on all measurements than the subjects with depressive symptoms. The figure suggests that there is a trend for subjects with strong social support scoring better on all measurements (except TUG test) than the subjects with weak social support.

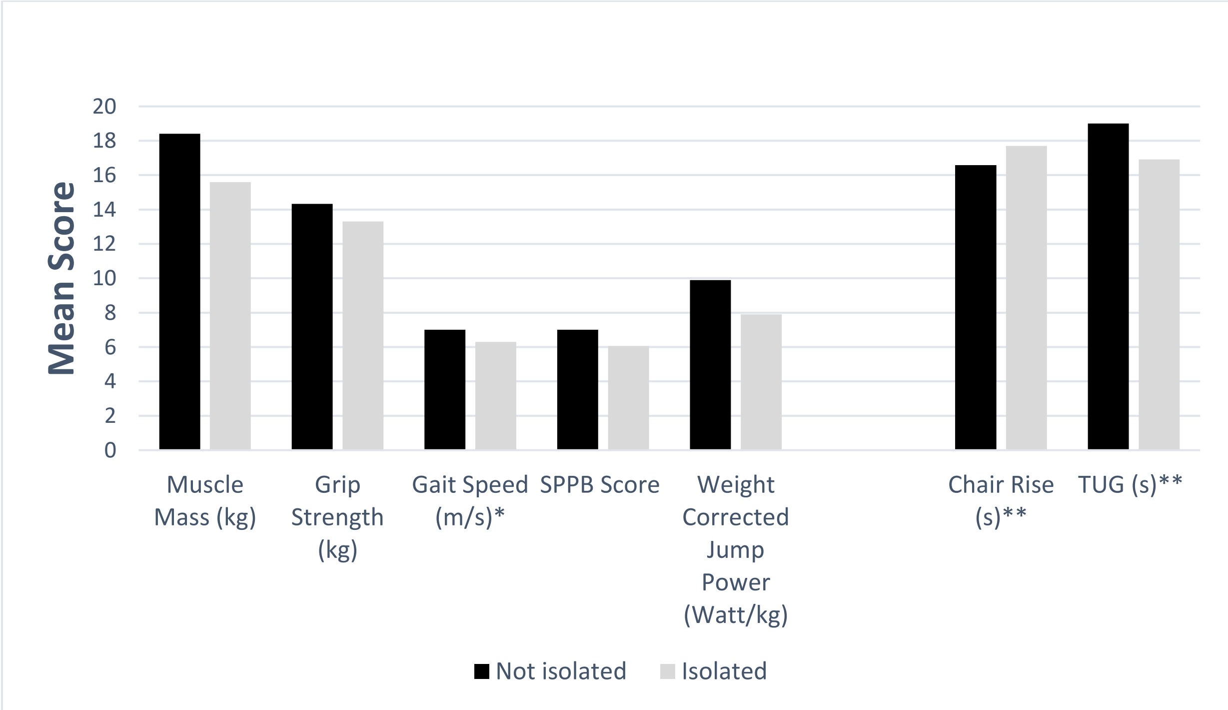
*Gait speed was scaled by a factor of 10 for the graph.
**Lower scores in chair rise and TUG tests indicate better performance.

(A)



*Gait speed was scaled by a factor of 10 for the graph.
**Lower scores in chair rise and TUG tests indicate better performance.

(B)



*Gait speed was scaled by a factor of 10 for the graph.
**Lower scores in chair rise and TUG tests indicate better performance.

(C)

Figure 5. Graphical Presentation of the Differences in Muscle Outcomes Based on the IVs. Self-efficacy (A), Depression (B), and Social support (C).

Convergent Validity of Muscle Mechanography

Convergent validity of MM was evaluated by examining the relationship between weight corrected jump power and grip strength, gait speed, chair rise, SPPB, and TUG tests. Pearson's product moment correlation coefficients were significant with each measure demonstrating convergent validity. Weight corrected jump power was significantly and positively correlated with GS, gait speed, and SPPB (r = .542, .716, and .777, respectively; $p < .01$). Weight corrected jump power was significantly and negatively correlated with chair rise and TUG (r = -.538 and -.638, respectively; $p < .01$). The results are detailed in Table 11.

Table 11
Correlation Coefficient Values Between Weight Corrected Jump Power, Muscle Mass, and Traditional Muscle Function Tests

Measure	1	2	3	4	5	6	*n*
1. SM	-						31
2. GS	.562**	-					31
3. Gait speed	.056	.172	-				31
4. Chair rise	-.113	-.213	-.652**	-			24
5. SPPB	-.123	.115	.787**	-.726**	-		31
6. TUG	-.106	-.403*	-.728**	.606**	-.633**	-	31
7. Weight corrected jump power	.262	.542**	.716**	-.538**	.777**	-.638**	30

*p< .05, ** p<.01
Note: SM: Total Skeletal Muscle Mass (kg), GS: Grip Strength (kg), Gait speed is measured by meter/second (m/s), Chair rise is measured by second (s), SPPB: Short Physical Performance Battery, TUG: Timed Up and Go and is measured by second (s), Weight corrected jump power is measured by Watt/kg.

Additional Findings

Description of Muscle Strength Based on EWGSOP

Participants were grouped into high and low grip strength based on the cut-off points established by the EWGSOP; the cut-off point for men is < 30 kg and for women < 20 kg (Cruz-

Jentoft et al., 2010). Eighty-nine percent of men (n=8) had low GS and only one man (11%) had high GS. All of the women (100%) had low GS (Table 12).

Table 12
Description of Muscle Strength (n = 31)

Measure	*n*	%	*M*	*SD*
GS	31		14	5.91
Male			21.78	4.32
<30 kg	8	89		
≥30 kg	1	11		
Female			10.82	2.5
<20 kg	22	100		
≥20 kg	0	0		

Note: GS: Grip Strength (kg).

Differences in Muscle Mass, Strength, and Function Based on the Incidence of Fall

An independent-samples t-test was conducted to compare mean scores of SM, GS, gait speed, chair rise, SPPB, TUG, and weight corrected jump power between individuals who had an incidence of fall in the past year and those who did not had an incidence of fall. A significant difference in the mean score of GS between individuals who did not had an incidence of fall (*M* = 15.67 kg, *SD* = 6.57) and individuals who had an incidence of fall (*M* = 11.7 kg, *SD* = 4.03); *t*(29) = 2.081, p = .047. The results are detailed in Table 13.

Table 13
Differences in Fall Incidence Based on Muscle Mass, Strength, and Function

	Falls		No Falls			
	M	*SD*	*M*	*SD*	*t*	*p*
SM	16.47	4.79	18.25	5.63	0.925	.363
GS	11.7	4.03	15.67	6.57	2.081	.047*
Gait speed	0.67	0.23	5.94	2.6	0.34	.738
Chair rise**	15.52	5.90	18.53	5.65	1.263	.225
SPPB	6.92	2.84	5.94	2.58	0.999	.326
TUG	19.1	10.02	17.69	5.28	0.499	.622
Weight corrected jump power***	7.64	5.09	9.27	5.87	0.793	.434

p< .05*, N = 31, **n=24, n=30*

Note: SM: Total Skeletal Muscle Mass (kg), GS: Grip Strength (kg).

Discussion

Little is known about the characteristics of muscle function and the association between cognitive and psychosocial factors and sarcopenia among older adults, particularly those who live in RCACs. This study described the muscle outcomes of older adults living in one RCAC and examined the relationship between self-efficacy for exercise, depression, and social support and muscle outcomes, including muscle mass, strength, and function. This study showed that the participants had poor muscle mass, strength, and function. Values of muscle outcomes were numerically lower in comparison with the values observed in most of other studies (Dietzel, Gast, Heine, Felsenberg, & Armbrecht, 2013; Tsubaki, Kubo, Kobayashi, Jigami, & Takahashi, 2009; Siglinsky et al., 2015). This is might due to fact that this study included frail and very old adults. The variability of inclusion and exclusion criteria across studies may also have an important impact on the findings. For instance, several studies included young individuals and excluded individuals with walking aids, those were unable to climb a standard staircase or unable to walk 800 m unaided, and those with any impairment of activities of daily living (Dietzel et al., 2013; Tsubaki et al., 2009; Siglinsky et al., 2015). Accordingly, it is not surprising that the included sample had low muscle mass, strength, and function scores as this study represented a vulnerable and understudied population.

A sex difference exists for muscle mass, grip strength, and Weight corrected jump power. Consistent with previously published values among community-dwelling older adults (Janssen, Heymsfield, Wang, & Ross, 2000; Yorke, Curtis, Shoemaker, & Vangsnes, 2015), men demonstrated significantly higher mean skeletal muscle mass and hand grip strength than women. Similar to previous study, the results also showed that men had significantly greater weight corrected jump power compared to women (Siglinsky et al., 2015). Although men performed slightly better than women on gait speed, chair rise, and TUG tests, women had slightly higher SPPB score than men. However, these differences were not statistically significant. These results are parallel to the available conflicting data regarding sex differences and physical function tests among community-dwelling older adults (Cooper et al., 2011; Fragala et al., 2012, Siglinsky et al., 2015).

While the study did not demonstrate significant associations between self-efficacy for exercise and muscle outcomes, the results showed a trend for individuals with high self-efficacy to have better scores on all muscle mass, strength, and function measurements than those with low self-efficacy. This trend is similar to results from a previous study that found an association between self-efficacy and physical function in older adults (Cooper, Huisman, Kuh, & Deeg, 2011). Self-efficacy is a main determinant of exercise and physical activity behaviors (McAuley et al., 2006), which both are among the most effective interventions to combat sarcopenia and functional limitations in older adults (Pillard, et al., 2011; Keysor, 2003; Morley, 2012). Despite the suggested protective effect of physical activity on muscle outcomes, physical activity behaviors and the practicality of exercise among older adults are remain questionable (Pillard et al., 2011). This is due to the different characteristics of older adults, including different levels of self-efficacy and outcome expectations as well as the physical, mental, and environmental obstacles. These barriers are considered a challenge for researchers and clinicians to help older adults to engage in or to increase physical activity or exercise (Lee, Arthur, & Avis, 2008). Addressing these aspects may maximize the effect of physical activity or exercise on muscle outcomes and prevent the onset or progression of sarcopenia among older adults.

Depressive symptoms were only significantly associated with poor performance on chair rise test. Besides, the results showed that individuals without depressive symptoms had greater muscle mass and strength, higher jump power, and better scores on the muscle function tests. Few previous studies have examined the association between depression and sarcopenia. Hsu and colleagues conducted a study among older men living in a retirement community and reported that older adults with depressive symptoms were significantly lower in muscle mass, strength, and function and had more physical dependence than those without depressive symptoms (Hsu et al., 2014). Kim and colleagues found similar results and reported a lower skeletal muscle mass in participants with depressive symptoms (Kim et al., 2011). Nevertheless, the latest report from Byeon and colleagues did not identify an association between depressive symptoms and muscle mass, strength, and function (Byeon et al., 2016). Although the association between sarcopenia and depression appeared inconsistent from the data of the latest observational studies, the findings of this study added to the growing evidence that depression can be a risk factor for sarcopenia.

This study did not find significant associations between social support and muscle mass, strength, and function. However, the findings showed that individuals with strong social support system had greater muscle mass and strength and performed better on the muscle function tests (except for TUG test) than those who were classified as socially isolated. These findings are congruent with previous study that found a significant association between poor social support and low grip strength (Lamarca et al., 2013), which is a major component of sarcopenia (Fielding et al., 2011). Research indicated that strong social support is a protective factor in physical function incapacity, as well as it impacts the level of physical activity and physical health in older adults (Golden, Conroy, & Lawlor, 2009; Seeman, & Chen, 2002; Gallant, 2003; Wallace et al., 2015; Yeom et al., 2008; Resnick, Orwig, Magaziner, & Wynne, 2002; Molloy, Dixon, Hamer, & Sniehotta, 2010). These findings suggest that social support may be a countermeasure against the adverse impact of physical inactivity on muscle outcomes, including muscle mass, strength, and function.

The study also examined the convergent validity of MM relative to the traditional muscle function and strength tests (i.e., gait speed, chair rise, SPPB, grip strength). MM can quantitively measure the muscle function parameters including muscle power. The two-leg countermovement jump test is the most widely used test to assess muscle power (i.e., weight corrected jump power). The main findings in this study demonstrated convergent validity across all the included measures of muscle function and strength in this study. Weight corrected jump power was significantly and positively correlated with GS, gait speed, and SPPB ($r = .542$, $.716$, and $.777$, respectively; $p < .01$). Weight corrected jump power was also significantly and negatively correlated with chair rise ($r = -.538$ and $-.638$, respectively; $p < .01$).

The findings from this study are congruent with results from previous studies that have compared weight corrected jump power with traditional muscle function and strength tests (Rittweger et al., 2004; Siglinsky et al., 2015). Siglinsky and colleagues reported a correlation between weight corrected jump power and grip strength, as well as between weight corrected jump power and gait speed, chair rise, and total SPPB score (Siglinsky et al., 2015). Another study showed high correlation between weight corrected jump power and gait speed, chair rise, and TUG (Rittweger et al., 2004). However, Rittweger and colleagues reported higher associations than those found in this study (Rittweger et al., 2004). This might be related to the fact that they recruited healthy individuals. Overall, these findings are consistent with the results from this study that weight corrected jump power correlates with traditional muscle function tests.

Previous research revealed that weight corrected jump power was best correlated with age and it is possible that MM may be superior to traditional tests at quantifying muscle function in older adults because of its higher correlation with age and good correlation with traditional muscle function tests and measured lean mass (Siglinsky et al., 2015). These results add to the clinical validity of MM and could potentially lead to greater sensitivity to change when monitoring exercise interventions in older adults. MM can be also useful in obtaining precise measures of muscle function and benchmarks for functional data among older adults.

Limitations

The study has several limitations including study design, sample size and methods. Causality cannot be inferred when descriptive-correlational study designs are used. A small convenience sample from one geographic region was utilized for this study so the findings may not be generalizable. The small sample size and inferential analyses used may have caused limited statistical power and led to a Type II error. In addition, there was a lack of control for all potentially confounding variables. Although pain was examined as a confounding variable, many other potentially confounding variables in this study were not controlled for and therefore the generalizability is limited and the results should be viewed with caution. Individuals with end-stage organ disease, cognitive impairment, recent injury or surgery that limits ability to move around, and those who were unable to stand without assistance were excluded. This limits generalizability to a broader population and the findings should be viewed with caution.

Another limitation is the use of muscle function tests (i.e., SPPB, TUG) presents some drawbacks mainly due to dichotomous (yes/no) determinations and being prone to human errors as the results depend on the times taken by individual examiners. Furthermore, although BIS is inexpensive, noninvasive, and well correlate with MRI and DXA predictions, the use of BIS to assess muscle mass has a limitation. Due to the common problem of dehydration in older adult patients, BIS underestimates fat tissue, resulting in artificially high fat-free mass values. In addition, although self-efficacy, depression, and social support were measured using validated scoring systems, the results may not be robust since they are limited to only one time measurement. Finally, the convergent validity of MM was tested in a homogeneous small group of older adults living in one RCAC and the results must be reviewed with caution.

Implications and Recommendation for Future Research

The findings from this study have important implications for the identification of sarcopenia and for nursing practice. The findings show that RCACs residents have poor muscle outcomes, including muscle mass, strength, and function. This vulnerable population should be the target of assessment and prevention strategies to attenuate the frequently reported declines in physical function and muscle outcomes. In addition, the study supports the evidence that sarcopenia is not only related to the ageing processes; there are several modifiable factors that may be important in the onset and progression of sarcopenia. Findings from the current study suggest that self-efficacy, depression, and social support may be modifiable factors associated with poor muscle outcomes. This may emphasize the importance of health promotion earlier in life and prevention planning to prevent sarcopenia and maintain better muscle mass, strength, and function.

Physical activity and exercise are among the most beneficial interventions for preventing sarcopenia and ameliorating muscle outcomes (Bruyère et al., 2016; Cruz-Jentoft et al., 2010; Pillard et al., 2011). Improving physical activity and exercise behaviors can be achieved through alleviating depressive symptoms and enhancing self-efficacy and social support (Resnick et al., 2002). This suggests interventions to improve physical activity and exercise behaviors among older adults should incorporate depression management and social support to strengthen self-efficacy and outcome expectations related to physical activity and exercise. Improving depressive symptoms also minimizes the negative impact of depression on muscle outcomes in older adults (Pillard et al., 2011; Schaap, Pluijm, Deeg, & Visser, 2006).

Nurses should play a major role in identifying those with poor muscle outcomes and improving physical activity and exercise behavior by providing frequent expert support and implementing self-efficacy-based interventions. Nurses should also employ new technology such as MM to predict the onset of physical function decline and evaluate the potential effect of nursing therapeutic interventions on muscle outcomes.

Finally, future longitudinal studies with large sample sizes are required to confirm the association between the studied variables and to examine other potential lifestyle behaviors that might contribute to sarcopenia and its reversibility. Such studies provide a rationale for the development and evaluation of effective, feasible, transferable and sustainable interventions implemented in RCAC settings. Finally, future research is needed to provide evidence about the validity of MM and its ability to identify small changes in older adults with a wide range of performance, as well as to examine whether MM is associated with geriatric outcomes such as sarcopenia, falls, and fractures. Such evidence supports the sensitivity of this methodology to intervention-induced changes in muscle function and the possibility of using MM in the clinical and research evaluation of sarcopenia among older adults.

Conclusion

Sarcopenia is major health problem among the aging population worldwide. This study is only one of a few to evaluate the relationship between selected cognitive and psychosocial factors and sarcopenia among older adults living in RCACs. The study suggests that RCACs have poor muscle mass, strength, and function. The findings support the hypothesis that depressive symptoms are associated with poor muscle function. The study also shows that the decline in muscle mass, strength, and function is seen more frequently in individuals with low self-efficacy level and poor social support. In addition, this study provides a new evidence about MM as a new technology to quantitively assess muscular function in older adults, potentially making this a valuable research tool.

Chapter Summary

This chapter reported the design, methods, sample, and setting of the study. The findings about self-efficacy for exercise, depression, social support, and muscle characteristics of RCACs residents, as well as the findings on the associations between the variables were presented. Limitations, implications, and recommendations for future research were discussed. The findings of this cross-sectional descriptive correlational study filled gaps in knowledge and contributed to the literature on risk factors for sarcopenia in older adults living in RCACs, and provided information about MM as a novel method to evaluate muscle function in older adults.

CHAPTER 5

Chapter Introduction

This chapter is focused on discussing the findings of the study. A discussion of how the specific findings are consistent with the adapted theoretical framework, and other research findings are presented. The limitations of the study and implications for nursing practice, health policy and education are discussed. Recommendations for future research and a concluding statement are presented.

Synthesis of Findings

Sarcopenia is a geriatric syndrome characterized by a reduction in muscle mass, strength, and function. This syndrome is highly prevalent and associated with functional decline and loss of independence in older adults. Understanding the etiology and risk factors of sarcopenia is an essential step towards the development of new methods for clinical diagnosis, new insights into the underlying mechanisms, and ultimately to the development of effective interventions for sarcopenia prevention and management. The findings of this study indicate that older adults living in RCACs have lower values of muscle mass, strength, and function in comparison with other values observed in many other studies (Dietzel et al., 2013; Siglinsky et al., 2015; Tsubaki et al., 2009). This indicates that this group of older adults may be at greater risk for negative health consequences than community dwelling older adults, such as fall, fractures, and being placed in more restricted living environment including nursing homes.

Consistent with other literature, findings from this study shows a trend for individuals with high self-efficacy, without depressive symptoms, and with strong social support to present greater muscle mass, strength, and function (Hsu et al., 2014; Kim et al., 2011; Lamarca et al., 2013). While there is no research to date that examines d the association between self-efficacy for exercise and sarcopenia, other studies found that self-efficacy is a key predictor for physical activity and exercise, both of which countermeasure functional decline and poor muscle outcomes (Keysor, 2003; McAuley et al., 2006; Pillard, et al., 2011). Several studies also demonstrate relationship between depressive symptoms and social support and muscle outcomes (Hsu et al., 2014; Kim et al., 2011; Lamarca et al., 2013). These findings highlight the importance of further exploring the examined factors and addressing them in future interventions to prevent, maintain, and improve muscle outcomes and functional capacity among older adults, particularly RCACs residents.

In addition, the development of interventions to mitigate sarcopenia and functional decline requires sensitive and reproducible testing methodologies. Similar to other studies, the current study provides new evidence about the validity of MM as a novel method to quantitively assess muscle function parameters in older adults. MM is found to be safe, valid, and sensitive method with greater ability to detect small changes in muscle function among older adults in comparison to the traditional muscle function tests such as gait speed and SPPB (Buehring et al., 2015; Siglinsky et al., 2015; Taani et al., 2017). Using such technology with good reproducibility and sensitivity could be useful in assessing for sarcopenia, evaluating the effectiveness of nursing intervention, and extending the nursing science.

Implications for Nursing Theory

Findings from the study show that older adults without depressive symptoms and with high self-efficacy and social support have greater muscle mass, strength, and function (although self-efficacy and social support were not significant). These findings are consistent with the adapted Individual and Family Self-Management Theory (IFSMT) framework (Ryan & Sawin, 2009) which suggests that context factors (e.g., depression and social support) and the self-management process (e.g., self-efficacy) may contribute to better self-management behaviors (physical activity, exercise, and healthy eating habits), and lead to improved health outcomes (better muscle mass, strength, and function). The findings from this study suggest that addressing the examined risk factors could be a helpful intervention for improving muscle outcomes among older adult living in RCACs.

The IFSMT could be used to provide theory-informed nursing interventions to improve muscle outcomes and prevent sarcopenia. Individual and family-centered interventions impact self-management behaviors addressing either the context or the self-management process. While interventions focused on the contextual factors can reduce risk or foster conditions that support self-management, interventions aimed at the self-management process can enhance knowledge and beliefs and increase the use of self-regulation behaviors. The findings from this study suggest that future research should focus on interventions to improve engaging in physical activity and exercise programs, managing depression, and developing a strong social network. These factors may play a role in RCACs residents' attitudes influencing their healthy behaviors including physical activity, exercise, and eating habits and ultimately their muscle outcomes.

Incorporating the concepts and assumptions of the IFSMT helped examine potential risk factors for sarcopenia from a nursing perspective. Nonetheless, the adapted theoretical framework used to guide this study is not yet comprehensive or final. The author suggests considering the adapted theoretical framework as a foundation for future nursing research. Nurses are encouraged to validate the findings of this study and generate empirical evidence on the relationship between the studied variables utilizing theory-testing approach. Continued use and testing of the IFSMT could result in expanding nursing knowledge related to self-management in older adults with sarcopenia and functional decline, as well as revealing concepts essential to self-management and determining what concepts are applicable for sarcopenia among older adults.

Implications for Education, Clinical Practice, and Policy

Implications for Nursing Education

Evidence from previous research revealed that providing care for older adults by healthcare professionals prepared in geriatrics leads to improvements in health outcomes, including better physical, functional, and psychosocial well-being without an increase in healthcare costs (Kovner, Mezey, & Harrington, 2002). Such improvement in health outcomes may also reduce cost. Therefore, increasing the geriatric content in undergraduate nursing curriculum could be a helpful strategy to raise awareness among nurses about chronic conditions in older adults and provide quality nursing care for older adults. Geriatric certifications and education programs should be offered to nurses to provide them with knowledge and skills required to assess and manage chronic conditions including sarcopenia and functional loss and to provide the highest quality care possible for their patients. More research is needed to determine if these educational initiatives actually improve patient outcomes and reduce cost.

The role of the nurse in disease prevention continues to be of utmost importance. Self-management is a crucial aspect to quality living and successful prevention and management of chronic conditions. The American Association of Colleges of Nursing (AACN) created the Essentials of Baccalaureate Education for Professional Nursing Practice document to disclose the important curricular elements and framework for developing the undergraduate nursing curriculum for the 21st century (AACN, 2008). The document emphasized the importance of integrating disease prevention and health behavior change theories into nursing courses. Following these recommendations, nursing courses should be modified regularly to reflect the current evidence-based self-management practice. The findings from this study can be used as an example to educate nursing students about the IFSMT, implications and ramifications of poor muscle outcomes, possible risk factors for sarcopenia, and how to promote self-management behaviors among their patients.

Implications for Clinical Practice

Nurses have a broad scope of practice that plays a significant role in improving patients' knowledge, behavior change, and health outcomes. Nurses are likely to encounter older adults with sarcopenia and functional decline in hospitals, nursing homes, assisted-living facilities, and in their own homes. Nurses are expected to develop holistic care plans to prevent sarcopenia and improve physical function and overall well-being of older adults. However, research shows that the routine assessment for sarcopenia is lacking and sarcopenia is commonly underdiagnosed and undertreated (Giuliani et al., 2008; Iolascon et al., 2014; Roberts et al., 2013; Zacker, 2006).

Assessment for sarcopenia and targeting older adults at high risk may be an important first step to prevent and manage functional decline (Beaudart et al., 2016; Fielding et al., 2011). Nurses have a significant role in identifying patients who are at risk for sarcopenia and functional decline, implementing nursing preventive measures, and referring them to specialists in the field (Hunt, Chapa, Hess, Swanick, & Hovanec, 2014; Zacker, 2006). This study provides information about risk factors for sarcopenia and encourage nurses to incorporate methods for screening such as gait speed and grip strength. The Red Flag and SARC-F questionnaires could also be useful to quickly and easily screen older adults for sarcopenia and functional decline during a standard health care (Beaudart et al., 2016; Cruz-Jentoft et al., 2014; Fielding et al., 2011). Integrating sophisticated methods such as MM in the clinical setting may be helpful to assess muscle function and detect those at risk for sarcopenia.

Patient-centered interventions such as motivational interviewing and collaborative goal setting were not examined in this study but may be helpful modalities to improve healthy behaviors. Motivational interviewing and collaborative goal setting may encourage patients to determine what changes are necessary - such as engaging in physical activity, improving nutritional intake, managing depression, and improving social support network - and how they can be achieved (Britt, Hudson, & Blampied, 2004; Handley et al., 2006). Nurses should also identify both individual and contextual health risk factors that hinder the capacity of older adults to promote their health behaviors. In addition, hospitalization leads to sarcopenia among older adults due to an increased inflammatory burden, malnutrition, and bed rest-related muscle disuse (Welch, Hassan-Smith, Greig, Lord, & Jackson, 2017). Nurses must take a lead role in prevention of sarcopenia and functional decline in hospitalized older adults through identifying patients at risk, mobility assessments, initiating exercises, managing malnutrition, and early mobilization. These practices may reduce the length of stay, hours needed to provide care, and adverse outcomes related to poor muscle outcomes and loss of functional capacity.

Implications for Health Policy

Preventing and managing sarcopenia require policy solutions and a wide range of interrelated programs and actions from both the public and private sectors. Using results from this study and other research on sarcopenia to raise awareness about risk factors for sarcopenia, its impact on health and well-being, and the importance of healthy lifestyles is a crucial step to prevent sarcopenia and ensure good muscle outcomes among older adults. Because the most effective approach to prevent sarcopenia is to promote physical activity, exercise, and proper nutrition (Cruz-Jentoft et al., 2010; Morley, 2012; Rom, Kaisari, Aizenbud, & Reznick, 2012), factors including the self-management behaviors in older adults' population and the lack of resources for exercise programs and appropriate nutrition should be a major concern for policy makers. Public policy should focus on increasing accessibility to public exercise facilities at little or no cost; implementing therapeutic foods supplementation solutions to reverse undernutrition; and providing health promotion and mental health counseling services (Bruyère et al., 2016; Rom et al., 2012).

Stakeholders from public health authorities, healthcare organizations, academia, research centers, consumers, and aging associations across the country should begin a national dialogue to discuss the importance of preventing sarcopenia and functional decline in older adults. Stakeholders should make an effort to secure funding and resources for future research, as sarcopenia is still relatively a new area of research. Supporting research in this area is crucial to better understand the etiology of sarcopenia and functional decline, establish standardized methodology for clinical assessment, and develop new intervention strategies. Furthermore, new policies are needed to tackle sarcopenia and functional decline upstream and to shift from reactive repair to proactive prevention paradigm (Mazières et al., 2017). These policies should include implementing a comprehensive care model for prevention of sarcopenia and functional decline in the clinical settings and long-term care facilities and offering interventions that are multidisciplinary, integrated and goal-oriented at the physical, social, and psychological domains of functional decline.

Limitations

Several limitations should be considered while interpreting the findings from this study. A cross-sectional descriptive correlational design was used, and therefore the results cannot be used to make causal claims among relationships of sarcopenia and the hypothesized associated factors. The study was focused on a small convenience sample from one RCAC and individuals with end-stage organ disease, recent injury or surgery, cognitive impairment, and those who were unable to stand without assistance were excluded. Therefore, the findings should not be generalizable to nursing home residents or healthy community-dwelling older adults and should be viewed with caution. The small sample size and statistical analysis techniques used in this study may have caused limited statistical power and led to a Type II error

Although pain was examined as a confounding variable, many other potentially confounding variables including current medical condition, severity of illness, and comorbidities were not controlled for. Thus, the generalizability is limited and the results should be viewed with caution. The study also has some measurement limitations. First, using the traditional muscle function tests (i.e., SPPB, TUG) presents some shortfalls mainly due to dichotomous (yes/no) determinations and being prone to human errors. Second, the use of BIS for muscle mass assessment has a limitation due to the dehydration problems usually observed in older adults, which may result in an underestimation of the fat tissue and an overestimation of fat-free mass. However, BIA is inexpensive, easy to use, reproducible, and considered as a portable alternative to DXA and MRI. Third, measuring self-efficacy, depression, and social support is limited to only one time measurement and future studies could use repeated measures for more robust findings. Finally, the convergent validity of MM was tested in a homogeneous small group of older adults living in one RCAC and the results must be interpreted with caution.

Recommendation for Research

Understanding the risk factors for sarcopenia and functional decline in RCACs residents has implications for future nursing research that could bridge the gap between research-generated evidence and nursing care. The findings from this study show a trend for individuals with high self-efficacy, without depressive symptoms, and with strong social support to present greater muscle mass, strength, and function. Future longitudinal studies with large sample sizes are required to confirm the association between the studied variables and to examine other potential lifestyle behaviors that might contribute to sarcopenia and its reversibility.

While self-management interventions are commonly complex with multiple components, the feasibility of these interventions should be investigated, particularly among RCACs residents. Such interventions could improve self-management behaviors and physical function and prevent sarcopenia in older adults. Testing the effect of variety of exercise programs, such as group-based exercise and vibration exercise, on physical function and muscle outcomes is also recommended. Measurement methods such MM can be used to evaluate the effectiveness of nursing interventions on physical function and muscle outcomes among older adults. Although the available results from several studies demonstrate the safety, practicality, and validity of MM; it's valuable to conduct future research to confirm these findings and to examine whether MM is associated with geriatric outcomes such as sarcopenia, falls, and fractures.

The recruitment process of the population of older adults, particularly RACAs residents can be lengthy and exhausting. In the original study, the author collaborated with social workers, physical therapists, and registered nurses who worked within the facility to recruit the greatest possible number of subjects and to ensure successful recruitment of the most representative sample of subjects. Another recommendation is to recruit from multiple facilities to reach the target sample size and to ensure sample representativeness. In addition, several strategies were used in the original study to reduce burden on the participants, including administering the questionnaire by interview, assessing whether the older adult is fatigued and wants to finish the questionnaires or muscle function tests after a one hour break or on another day. Both strategies were found to be effective in reducing the burden on the participants.

Conclusion

Sarcopenia, the decline in muscle mass, strength, and function, is associated with functional loss and disability among older adults. The findings show that RCACs residents have poor muscle outcomes, which may affect their everyday functions and make them at high risk for falls and fractures. The poor muscle outcomes are also seen more often in those with depressive symptoms and low self-efficacy and social support. These contextual and self-management process-related factors may have important roles in the development of sarcopenia. The study also provides evidence about the validity of MM as a tool to quantitively assess muscle function in older adults. Such tools can also be used in research setting to assess the effect of nursing intervention on muscle outcomes.

Chapter Summary

The current study revealed that older adults living in RCACs have low muscle outcomes, and these poor outcomes are more prevalent in individuals with depressive symptoms and with low-self-efficacy and social support. Nurses has the responsibility to take a lead role in the prevention of sarcopenia and functional decline in older adults through individual-centered care, education, and motivation. Nurse educators are also encouraged to improve the quality of nursing education by integrating geriatric content to meet the health needs of the growing population of older adults. Moreover, since chronic health conditions are highly prevalent among older adults such sarcopenia and functional loss, there is a necessity to design and develop nursing intervention to mitigate sarcopenia and improve physical function in older adults. MM can be integrated in designing and evaluating specific nursing interventions aimed at improving physical function and muscle outcomes in older adults. In summary, the results of this study necessitate a broader examination of the risk factors for sarcopenia, exploring potential intervention modalities, and employing sophisticated methods in this area of research.

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APPENDICES

Appendix A: Studies Addressing the Risk Factors for Sarcopenia in Older Adults

Author, Year	Purpose	Design, Sample Size, Age	Measure	Outcome Measure
Alexandre et al. (2014)	Examine the prevalence and factors associated with sarcopenia in community dwelling older adults	Correlational, cross-sectional n = 1149 ≥ 60 years	The Mini Mental State Exam (MMSE), the International Physical Activity Questionnaire (IPAQ), Geriatric Depression Scale (GDS), Mini-Nutritional Assessment (MNA), skeletal muscle mass index using the Lee equation, handgrip strength, and gait speed	Cognitive impairment (OR 2.68, 95% CI 1.23–5.84), lower income (OR 2.57, 95% CI 1.06–6.20), smoking (OR 2.00, 95% CI 1.11–3.63), undernutrition (OR 11.54, 95% CI 3.45–38.59) and risk for undernutrition (OR 3.15, 95% CI 2.03–4.89) were factors associated with sarcopenia
Byeon et al. (2016)	Examine the relationship between sarcopenia and depression in community dwelling older adults by age group and obesity status	Correlational, cross-sectional n = 7,364 Age was categorized into three groups (20 - 39, 40 - 59, and ≥ 60 years)	Body Max Index (BMI), depressive symptoms, and appendicular skeletal muscle mass via Dual Energy X-ray Absorptiometry (DXA)	No significant associations between sarcopenia and depression among all age groups
Castillo et al. (2003)	Examine the prevalence and factors associated with sarcopenia in community-dwelling older adults	Correlational, cross-sectional n = 1700 65-98 year-old	Medical conditions, medication use, Bioimpedance Spectroscopy (BIS), grip strength, alcohol intake, smoking status, physical activity level, and BMI	Lack of physical activity and current smoking are risk factors for sarcopenia

Author, Year	Purpose	Design, Sample Size, Age	Measure	Outcome Measure
Figueiredo et al. (2014)	Analyze the prevalence of sarcopenia and associated risk factors in community-dwelling older adults	Correlational, cross-sectional n = 399 Mean age = 74.2 years	Lifestyle, race, medical history, BMI, DXA	BMI (OR 0.45, 95% CI 0.36–0.57), black race (OR 0.27, 95% CI 0.08–0.88), current smoking (OR 3.44, 95% CI 1.18–9.96), physical activity (OR 0.28, 95% CI 0.08–0.95), and total femur bone mineral density (OR 0.019, 95% CI 0.0003–0.98) were risk factors for sarcopenia
Gariballa & Alessa (2013)	Identify the clinical determinants and prognostic significance of sarcopenia in a cohort of hospitalized acutely ill older patients	Correlational, cross-sectional n = 432 ≥ 65 years	Medical conditions, history of chronic illnesses, smoking status, alcohol and drug intake, nutritional status, Barthel Index of Activities of Daily Living, muscle strength-hand grip, and muscle mass measured by mid-arm muscle circumference	Depression symptoms and lower serum albumin concentration were associated factors for sarcopenia
Gianoudis et al. (2014)	Examine the relationship between total sitting and TV viewing time on sarcopenia in community-dwelling older adults	Correlational, cross-sectional n = 162 60 – 86 years	Three repetition maximum testing 30 s sit-to-stand, four square step test, the timed-up-and-go (TUG) test, timed stair climb test, and total sitting and TV viewing time via questionnaire	Overall sitting time 1+hr/day the risk of sarcopenia increased by 33 % (OR 1.33, 95% CI 1.05, 1.68)
Han et al. (2016)	Examine the prevalence and factors associated with sarcopenia in community-dwelling older adults	Correlational, cross-sectional n = 1,069	Medical conditions, educational level, smoking and drinking habits, history of falls, physical	Presence of sarcopenia was inversely associated with BMI for both sexes. Diabetes in males (OR 5.04, 95% CI 1.70–14.89),

Author, Year	Purpose	Design, Sample Size, Age	Measure	Outcome Measure
		≥ 60 years	activity level, GDS, BIS, gait speed, and grip strength	diabetes in females (OR 2.36, 95% CI 1.06–5.25), daily consumption of alcohol (OR 10.60, 95% CI 1.75–64.24), peptic ulcer in female (OR 5.58, 95% CI 2.13–14.59) were associated risk factors for sarcopenia
Hsu et al. (2014)	Evaluate the association of cognitive impairment, depressive mood and sarcopenia among older men living in the veterans retirement community	Correlational, cross-sectional n = 353 ≥ 65 years	ADL, gait speed, handgrip strength, BMI, BIA, MMSE, and GDS	Sarcopenia was associated with cognitive impairment (OR 3.03, 95% CI 1.63–5.65) and depressive symptoms (OR 2.25, 95% CI 1.03–4.89) Older adults with sarcopenia were significantly lower in BMI compared to those who did not have sarcopenia
Kim et al. (2011)	Examine the relationship between depression and various components of body composition, including fat and muscle, in community-dwelling older adults	Correlational, cross-sectional n = 836 ≥ 60 years	GDS, abdominal visceral fat area and subcutaneous fat area via Computed Tomography (CT), appendicular skeletal muscle mass via DXA	Depression was associated with low BMI and sarcopenia. The risk of depression was lower with higher appendicular skeletal muscle mass (OR 0.49; 95% CI 0.29–0.85) and lower with higher BMI (OR 0.70, 95% CI 0.51–0.96). Depression was negatively associated with BMI in women (OR 0.73; 95% CI 0.56–0.95)

Author, Year	Purpose	Design, Sample Size, Age	Measure	Outcome Measure
Landi et al. (2012)	Evaluate the prevalence of sarcopenia and its association with functional and clinical status in nursing home residents	Correlational, cross-sectional n = 122 ≥ 70 years	ADL via Minimum Data Set assessment form for the nursing Home (MDS-NH), cognitive performance, BMI, gait speed, hand grip strength, and BIS	Cerebrovascular disease (OR 5.16, 95% CI 1.03–25.87), osteoarthritis (OR 7.24, 95% CI 2.02–25.95) were associated risk factors for sarcopenia. Risk of sarcopenia negatively associated with BMI >21kg/m^2 (OR 0.76, 95% CI 0.64-0.90), physical activity 1+hr/day (OR 0.40, 95% CI 0.12-0.98)
Lau et al. (2005)	Evaluate the prevalence of and risk factors for sarcopenia in community-dwelling older adults	Correlational, cross-sectional n = 527 ≥ 70 years	medical conditions, DXA, alcohol consumption, smoking status, regular exercise, and BMI	BMI < 18.5 was a significant risk factor for sarcopenia in men (OR 39.1, 95% CI 11.3–134.6) and women (OR 9.7, 95% CI 2.8–33.8)
Lee et al. (2007)	Examine the association between sarcopenia and common chronic illnesses, lifestyle factors, psychosocial well-being and physical performance in community-dwelling older adults	Correlational, cross-sectional n = 4000 ≥ 65 years	Medical illnesses, smoking status, alcohol consumption, Physical activity scale of the elderly (PASE), GDS, grip strength, timed chair-stands, gait speed, and DXA	Sarcopenia was associated with cigarette smoking (OR -0.19, 95% CI -0.31, -0.07), chronic illnesses (diabetes, hypertension, heart disease, COPD), underweight (OR -1.28, 95% CI -1.47, -1.29), and physical inactivity (OR -0.27, 95% CI -0.37, -0.17)
Martins, Bôas,	Identify the prevalence of	Correlational, cross-sectional	Socioeconomic and demographic status,	Retirement (OR 2.165, CI:95% CI 1.037 - 4.250) and smoking

Author, Year	Purpose	Design, Sample Size, Age	Measure	Outcome Measure
McLellan (2016)	sarcopenia and its association with anthropometric and socioeconomic factors in older adult patients assisted by primary health care	n = 136 ≥ 60 years	anthropometric profile was assessed, BIS, grip strength, and dietary intake	(OR 9.435, 95% CI 1.228 - 72.499) were risk factors for sarcopenia
Murphy et al. (2013)	Examine the time course of sarcopenia and to explore potential determinants of transition between stages of sarcopenia in community-dwelling older adults	Correlational, retrospective, longitudinal study (9-year follow-up) n = 2928 70 - 79 years	DXA, gait speed, grip strength, BMI, physical activity level, pain, smoking status	History of pain (OR 1.18, 95% CI 1.01–1.39) and higher BMI (OR 1.30, 95% CI 1.25–1.36) were predictive of transition from normal state into sarcopenic state
Santos et al. (2015)	Analyze whether sarcopenia is associated with sociodemographic factors and chronic noncommunicable diseases in community-dwelling older adults	Correlational, cross-sectional n = 120 80 – 95 years	Education level, chronic noncommunicable diseases, ethnicity, BMI, and DXA	Nutritional status (OR 5.14, 95% CI 1.94-13.57) was associated with sarcopenia
Senior et al. (2015)	Evaluate the prevalence and risk factors of sarcopenia among nursing home residents	Correlational, cross-sectional n = 102 ≥ 60 years	BIA, grip strength, gait speed, Short Physical Performance Battery (SPPB), MNA, GDS, MMSE, and IPAQ	BMI (OR = 0.80, 95% CI 0.65–0.97), low physical performance (OR 0.83, 95% CI 0.69–1.00), nutritional status (OR 0.19, 95% CI 0.05–0.68) and sitting time

Author, Year	Purpose	Design, Sample Size, Age	Measure	Outcome Measure
				(OR 1.18, 95% CI 1.00–1.39) were risk factors for sarcopenia
Tasar et al. (2015)	Investigate the prevalence of sarcopenia and its influencing factors in the local elderly nursing home residents	Correlational, cross-sectional n = 211 ≥ 65 years	Smoking and alcohol intake status, medications use, number and types of chronic diseases, upper arm circumferences, BMI, SPPB, and BIS	Malnutrition (OR 0.533, 95% CI 0.292–0.974) and current smoking (OR 2.289, 95% CI 1.063–4.929) were risk factors for sarcopenia
Volpato et al. (2014)	Estimate the prevalence and clinical correlates of sarcopenia in community-dwelling older adults	Correlational, cross-sectional n = 730 ≥ 65 years	BIA, gait speed, smoking habit, education level, physical activity, nutritional status, comorbidities, Center for Epidemiologic Studies Depression scale, MMSE, and blood sample	Lower insulin-like growth factor I (OR 3.89, 95% CI 1.03–14.1) and low bioavailable testosterone (OR 2.67, 95% CI 1.31–5.44) were associated with sarcopenia. A decreased probability of being sarcopenic was detected for individuals with higher level of education (OR 0.85, 95% CI 0.74–0.98). Nutritional intake, physical activity, and level of comorbidity were not associated with sarcopenia
Yalcin et al. (2015)	Evaluate the prevalence of sarcopenia and associated factors with sarcopenia among nursing home residents	Correlational, cross-sectional n = 141	Barthel Index of Activities of Daily Living, MMSE, MNA, BMI, handgrip strength, gait speed, BIS	BMI was associated with sarcopenia (OR 2.91, 95% CI 1.18-7.16)

Author, Year	Purpose	Design, Sample Size, Age	Measure	Outcome Measure
		≥ 65 years		
Yu et al. (2014)	Examined the incidence and the reversibility of sarcopenia and their associated factors over a 4-year period in community-dwelling older adults	Correlational, cohort, longitudinal study (4-year follow-up) n = 4000 ≥ 65 years	Medical conditions, dietary intake, education level, physical activity level, DXA, grip strength, and gait speed	Stroke (OR 2.56, 95% CI 1.32–4.95), Instrumental ADL impairment (OR 2.12, 95% CI 1.49–3.02), COPD (OR 1.84, 95% CI 1.02–3.31), BMI (OR 0.66, 95% CI 0.62–0.70), physical activity (OR 0.995, 95% CI 0.991–0.999) were risk factors for sarcopenia

- $P < 0.05$ is statistically significant

Appendix B: Short Physical Performance Battery (SPPB) Instructions

Read the instructions that are in ***bold and italic*** aloud.

> ***This is a physical performance test that has three main components: an assessment of balance, gait speed and chair rise time.***

General Notes:

- If a patient is not able to complete a test, record the reason, stop the balance tests, and move on.
- All tests are done with eyes open. Patients can move their arms to stabilize, but can not grab onto any objects or people.
- Walking aids are not permitted during the balance tests.

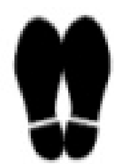
1. BALANCE TESTS

The patient must be able to stand unassisted *without the use of a cane or walker*. You may help the patient to get up.

> ***Now let's begin the evaluation. I would now like you to try to move your body in different movements. I will first describe and show each movement to you. Then I'd like you to try to do it. If you cannot do a particular movement, or if you feel it would be unsafe to try to do it, tell me and we'll move on to the next one. Let me emphasize that I do not want you to try to do any exercise that you feel might be unsafe.***
>
> ***Do you have any questions before we begin?***

A. Side-by-Side Stand

1. ***Now I will show you the first movement.***
2. (Demonstrate) ***I want you to try to stand with your feet together, side-by-side, for about 10 seconds.***
3. ***You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Try to hold this position until I tell you to stop.***

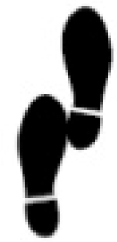


4. When the patient has his/her feet together, ask ***"Are you ready?"***
5. Then let go and begin timing as you say, ***"Ready, begin."***
6. Stop the stopwatch and say ***"Stop"*** after 10 seconds or when the patient steps out of position or grabs your arm.
7. If patient is unable to hold the position for 10 seconds, record result and move on.

B. Semi-Tandem Stand

1. ***Now I will show you the second movement***.

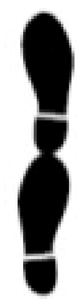
2. (Demonstrate) ***Now I want you to try to stand with the side of the heel of one foot touching the big toe of the other foot for about 10 seconds. You may put either foot in front, whichever is more comfortable for you.***
3. ***You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Try to hold this position until I tell you to stop.***



4. When the patient has his/her feet together, ask ***"Are you ready?"***
5. Then let go and begin timing as you say ***"Ready, begin."***
6. Stop the stopwatch and say ***"Stop"*** after 10 seconds or when the patient steps out of position or grabs your arm.
7. If patient is unable to hold the position for 10 seconds, record result and go to the gait speed test.

C. Tandem Stand

1. ***Now I will show you the third movement***.
2. (Demonstrate) ***Now I want you to try to stand with the heel of one foot in front of and touching the toes of the other foot for about 10 seconds. You may put either foot in front, whichever is more comfortable for you.***
3. ***You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Try to hold this position until I tell you to stop.***



4. Supply just enough support to the patient's arm to prevent loss of balance.
5. When the patient has his/her feet together, ask ***"Are you ready?"***
6. Then let go and begin timing as you say, ***"Ready, begin."***
7. Stop the stopwatch and say ***"Stop"*** after 10 seconds or when the patient steps out of position or grabs your arm.

2. GAIT SPEED TEST

Now I am going to observe how you normally walk. If you use a cane or other walking aid and you feel you need it to walk a short distance, then you may use it.

A. First Gait Speed Test

1. ***This is our walking course. I want you to walk to the other end of the course at your usual speed, just as if you were walking down the street to go to the store.***
2. Demonstrate the walk for the patient.
3. ***Walk all the way past the other end of the tape before you stop. Do you feel this would be safe?***
4. Have the patient stand with both feet touching the starting line.
5. ***When I want you to start, I will say: "Ready, begin."*** When the patient acknowledges this instruction say: ***"Ready, begin."***
6. Press the start/stop button to start the stopwatch as the patient begins walking.
7. Stop timing when one of the patient's feet is completely across the end line.

B. Second Gait Speed Test

1. ***Now I want you to repeat the walk. Remember to walk at your usual pace, and go all the way past the other end of the course.***
2. Have the patient stand with both feet touching the starting line.
3. ***When I want you to start, I will say: "Ready, begin."*** When the patient acknowledges this instruction say: ***"Ready, begin."***
4. Press the start/stop button to start the stopwatch as the patient begins walking.
5. Walk behind and to the side of the patient.
6. Stop timing when one of the patient's feet is completely across the end line.

3. CHAIR STAND TEST

A. Single Chair Stand

1. ***Let's do the last movement test. Do you think it would be safe for you to try to stand up from a chair without using your arms?***
2. ***This test measures the strength in your legs.***
3. (Demonstrate and explain the procedure.) ***First, fold your arms across your chest and sit so that your feet are on the floor; then stand up keeping your arms folded across your chest.***
4. ***Please stand up keeping your arms folded across your chest. Are you ready? Stand.*** (Record result).
5. If patient cannot rise without using arms, say ***"Okay, try to stand up using your arms. Are you ready? Stand."*** This is the end of their test. Record result and go to the scoring page.

B. Repeated Chair Stands

1. ***Do you think it would be safe for you to try to stand up from a chair five times without using your arms?***
2. ***Please stand up straight as QUICKLY as you can five times, without stopping in between. After standing up each time, sit down and then stand up again. Keep your arms folded across your chest. I'll be timing you with a stopwatch. Remember, if you cannot complete this test or if you feel it would be unsafe to do so tell me and we will quit.***
3. When the patient is properly seated, say: ***"Are you ready? Stand"*** and begin timing.
4. Count out loud as the patient arises each time, up to five times.
5. Stop if patient becomes tired or short of breath during repeated chair stands.
6. Stop the stopwatch when he/she has straightened up completely for the fifth time.
7. Also stop:

   • If patient uses his/her arms

- After 1 minute, if patient has not completed rises
- At your discretion, if concerned for patient's safety

8. If the patient stops and appears to be fatigued before completing the five stands, confirm this by asking ***"Can you continue?"***
9. If patient says "Yes," continue timing. If patient says "No," stop the stopwatch.

Appendix C: Timed Up & Go Test (TUG) Instructions

Directions:

The timed “Up and Go” test measures, in seconds, the time taken by an individual to stand up from a standard arm chair (approximate seat height of 46 cm [18in], arm height 65 cm [25.6 in]), walk a distance of 3 meters (118 inches, approximately 10 feet), turn, walk back to the chair, and sit down. The subject wears their regular footwear and uses their customary walking aid (none, cane, walker). No physical assistance is given. They start with their back against the chair, their arms resting on the armrests, and their walking aid at hand. They are instructed that, on the word “go” they are to get up and walk at your normal pace to a line on the floor 3 meters away, turn, return to the chair and sit down again. The subject walks through the test once before being timed in order to become familiar with the test. Either a stopwatch or a wristwatch with a second hand can be used to time the trial.

Instructions to the patient:

“When I say ‘go’ I want you to stand up and walk to the line, turn and then walk back to the chair and sit down again. Walk at your normal pace.”

Scoring:

Time for ‘Up and Go’ test _________sec.

☐ Unstable on turning?

☐ Walking aid used?   Type of aid: ___________

Appendix D: Self-Efficacy for Exercise Scale

How confident are you right now that you could exercise 3 times per week for 20 minutes if:

	Not Confident										Very Confident
1. You were worried the exercise would cause further pain	0	1	2	3	4	5	6	7	8	9	10
2. You were bored by the program or activity	0	1	2	3	4	5	6	7	8	9	10
3. You were not sure exactly what exercises to do	0	1	2	3	4	5	6	7	8	9	10
4. You had to exercise alone	0	1	2	3	4	5	6	7	8	9	10
5. You did not enjoy it	0	1	2	3	4	5	6	7	8	9	10
6. You were too busy with other activities	0	1	2	3	4	5	6	7	8	9	10
7. You felt tired during or after exercise	0	1	2	3	4	5	6	7	8	9	10
8. You felt stressed	0	1	2	3	4	5	6	7	8	9	10
9. You felt depressed	0	1	2	3	4	5	6	7	8	9	10
10. You were afraid the exercise would make you fall	0	1	2	3	4	5	6	7	8	9	10
11. You felt pain when exercising	0	1	2	3	4	5	6	7	8	9	10

Appendix E: Geriatric Depression Scale

Instructions: Circle the answer that best describes how you felt over the past week.

1.	Are you basically satisfied with your life?	yes	no
2.	Have you dropped many of your activities and interests?	yes	no
3.	Do you feel that your life is empty?	yes	no
4.	Do you often get bored?	yes	no
5.	Are you in good spirits most of the time?	yes	no
6.	Are you afraid that something bad is going to happen to you?	yes	no
7.	Do you feel happy most of the time?	yes	no
8.	Do you often feel helpless?	yes	no
9.	Do you prefer to stay at home, rather than going out and doing things?	yes	no
10.	Do you feel that you have more problems with memory than most?	yes	no
11.	Do you think it is wonderful to be alive now?	yes	no
12.	Do you feel worthless the way you are now?	yes	no
13.	Do you feel full of energy?	yes	no
14.	Do you feel that your situation is hopeless?	yes	no
15.	Do you think that most people are better off than you are?	yes	no

Total Score ________________

Appendix F: Lubben Social Network Scale-6 (LSNS-6)

FAMILY: *Considering the people to whom you are related by birth, marriage, adoption, etc…*

1. How many relatives do you see or hear from at least once a month?
   0 = *none* 1 = *one* 2 = *two* 3 = *three or four* 4 = *five thru eight* 5 = *nine or more*

2. How many relatives do you feel at ease with that you can talk about private matters?
   0 = *none* 1 = *one* 2 = *two* 3 = *three or four* 4 = *five thru eight* 5 = *nine or more*

3. How many relatives do you feel close to such that you could call on them for help?
   0 = *none* 1 = *one* 2 = *two* 3 = *three or four* 4 = *five thru eight* 5 = *nine or more*

FRIENDSHIPS: *Considering all of your friends including those who live in your neighborhood*

4. How many of your friends do you see or hear from at least once a month?
   0 = *none* 1 = *one* 2 = *two* 3 = *three or four* 4 = *five thru eight* 5 = *nine or more*

5. How many friends do you feel at ease with that you can talk about private matters?
   0 = *none* 1 = *one* 2 = *two* 3 = *three or four* 4 = *five thru eight* 5 = *nine or more*

6. How many friends do you feel close to such that you could call on them for help?
   0 = *none* 1 = *one* 2 = *two* 3 = *three or four* 4 = *five thru eight* 5 = *nine or more*

LSNS-6 total score is an equally weighted sum of these six items. Scores range from 0 to 30

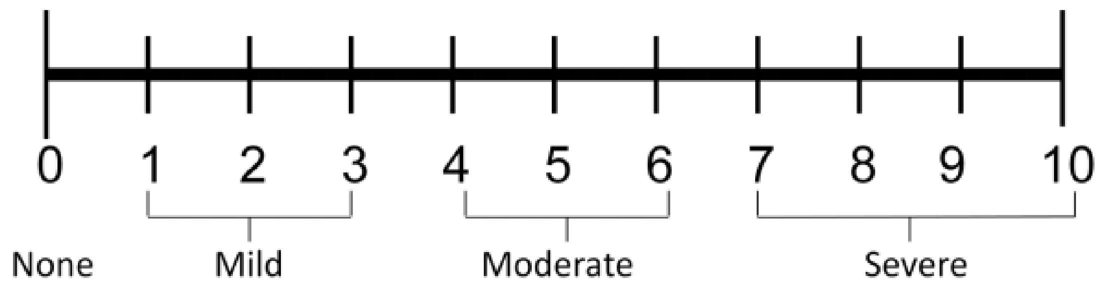
Appendix G: Numeric Pain Rating (NPR) Scale

General Information:

- The patient is asked to make three pain ratings, corresponding to current, best and worst pain experienced over the past 24 hours.
- The average of the 3 ratings was used to represent the patient's level of pain over the previous 24 hours.

Patient Instructions (adopted from (McCaffery, Beebe et al. 1989):

"Please indicate the intensity of current, best, and worst pain levels over the past 24 hours on a scale of 0 (no pain) to 10 (worst pain imaginable)"



Appendix I: Data Analysis Plan

Research questions/Hypotheses	Unit of Analysis	Variable	Measurement tool	Level of Measurement	Statistical Test
Descriptive Questions					
1. What are the self-efficacy for exercise, depression, and social support of older adults living in RCACs?	Resident subject	-Self-efficacy for exercise -Depression -Social support	-SEE -GDS-15 -LSNS-6	All ordinal	Descriptive (Frequency, mean, SD, range)
2. What are the muscle mass, strength, and function of older adults living in RCACs?	Resident subject	-Muscle mass -Muscle strength -Muscle function	-Muscle mass -Grip strength -Gait speed -Chair rise -SPPB -TUG -Jump power	All ordinal	Descriptive (Frequency, mean, SD, range)
Hypotheses					
1. Participants with high self-efficacy for exercise will have greater muscle mass, strength, and function than those with low self-efficacy for exercise	Resident subject	IV: -Self-efficacy for exercise DVs: -Muscle mass -Muscle strength -Muscle function	-SEE -Muscle mass -Grip strength -Gait speed -Chair rise -SPPB -TUG - Jump power	All ordinal	t-test
2. Participants without depressive symptoms will have greater muscle mass, strength, and function than those with depressive symptoms	Resident subject	IV: -Depression DVs: -Muscle mass -Muscle strength -Muscle function	-GDS-15 -Muscle mass -Grip strength -Gait speed -Chair rise -SPPB -TUG - Jump power	All ordinal	t-test
3.Participants with high social support will have greater muscle mass, strength, and function than those with low social support	Resident subject	IV: -Social support DVs: -Muscle mass -Muscle strength -Muscle function	-LSNS-6 -Muscle mass -Grip strength -Gait speed -Chair rise	All ordinal	t-test

			-SPPB -TUG - Jump power		
4. Weight corrected jump power obtained by MM correlates well with other traditional muscle function and strength tests, including SPPB, TUG, and grip strength.	Resident subject	-Muscle function -Muscle strength	-Grip strength -Gait speed -Chair rise -SPPB -TUG - Jump power	All ordinal	Correlation Coefficient Values

Appendix J: CURRICULUM VITAE

Murad Hekmat Taani

Education

BSN, Jordan University of Science and Technology, Faculty of Nursing, May 2007

MPH, New Mexico State University, Department of Public Health Sciences, August 2014

Dissertation Title: Cognitive and Psychosocial Factors Associated with Sarcopenia in Older Adults

Publications:

1. **Taani, M. H.**, Kovach, C. R., Buehring, B. (2017). Muscle mechanography: A novel method to measure muscle function in older adults. *Research in Gerontological Nursing, 10*(1) 17-24. doi:10.3928/19404921-20161209-03

2. Rao, S. P., **Taani, M.**, Lozano, V., & Kennedy, E. E. (2015). Educating students about suicide: A framework for the use of fotonovelas on college campuses. *College Student Journal*, *49*(2), 217-224.

3. Rao, S. P., Lozano, V., & **Taani, M.** (2014). Cues to healthy decision-making among college students: Results from a pilot study. *College Student Journal*, *48*(4), 697-704.