THE RELATION BETWEEN SARCOPENIA, PHYSICAL ACTIVITY, AND COGNITIVE FUNCTION IN COMMUNITY-DWELLING OLDER ADULTS IN MALAYSIA: A CROSS-SECTIONAL STUDY

LEE ANN KEE

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by

LEE ANN KEE

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LIST OF ABBREVIATIONS

AC	Arm Circumference
AD	Alzheimer's Disease
ALM	Appendicular Lean Mass
ASM	Appendicular Skeletal Muscle
AWGS	Asian Working Group for Sarcopenia
BADL	Basic Activities of Daily Living
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
CC	Calf Circumference
CHARLS	China Health and Retirement Longitudinal Study
CNS	Central Nervous System
DSST	Digit Symbol Substitution Test
DXA	dual-energy X-ray absorptiometry
ELSA	English Longitudinal Study of Ageing
EWGSOP	European Working Group on Sarcopenia in Older People
FFM	Fat-Free Mass
GS	Gait Speed
HEPA	Health-Enhancing Physical Activity
HGS	Handgrip Strength
IADL	Instrumental Activities of Daily Living
IWGS	International Working Group of Sarcopenia
KRT	Kawasan Rukun Tetangga
MCI	Mild Cognitive Impairment
MMSE	Mini-Mental State Examination
MNA	Mini Nutritional Assessment
MoCA	Montreal Cognitive Assessment
PA	Physical Activity
PASE	Physical Activity Scale for the Elderly
PAWE	Pusat Aktiviti Warga Emas
PCDS	Physio-Cognitive Decline Syndrome
RDA	Recommended Dietary Allowance

RE	Resistance Exercise
SES	Socioeconomic Status
SMI	Skeletal Muscle Index
SMM	Skeletal Muscle Mass
SPPB	Short Physical Performance Battery
TBW	Total Body Water
TMT	Trail Making Test
TSHA	Toledo Study of Healthy Aging

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HUBUNGKAIT SARCOPENIA, AKTIVITI FIZIKAL DAN FUNGSI KOGNITIF DALAM KALANGAN WARGA EMAS MALAYSIA YANG MENETAP DALAM KOMUNITI: KAJIAN KERATAN RENTAS

ABSTRAK

Kajian ini adalah untuk menilai prevalensi sarcopenia dalam kalangan warga emas Malaysia yang tinggal di dalam komuniti serta hubungkait sarcopenia dengan fungsi kognitif dan tahap aktiviti fizikal warga emas. Warga emas berumur 60 tahun ke atas yang menetap di bandar-bandar yang mempunyai kadar penduduk warga emas yang tinggi telah diajak untuk menyertai kajian ini. Penilaian sarcopenia merangkumi Jisim Otot-Rangka (SMI), kekuatan genggaman tangan (HGS), dan Short Physical Performance Battery (SPPB) yang mengikuti kriteria Asian Working Group for Sarcopenia (AWGS2). Peserta dianggap menghidapi sarcopenia jika kedua-dua jisim otot dan kekuatan/prestasi rendah. Peserta dengan ketiga-tiga kriteria (jisim otot, kekuatan, dan prestasi rendah) diklasifikasikan sebagai severe sarcopenia. Manakala, jika jisim otot mencukupi tetapi kekuatan atau prestasi otot rendah, peserta dikategorikan sebagai possible sarcopenia. Penilaian fungsi kognitif menggunakan: 1) Montreal Cognitive Assessment (MoCA) untuk pentaksiran mild cognitive impairment, 2) Trail Making Test (TMT-A dan TMT-B) menentukan kelajuan pemprosesan dan kelenturan kognitif, dan 3) Digit Symbol Substitution Test (DSST) pentaksiran keupayaan pemprosesan maklumat. Tahap aktiviti fizikal (PA) diukur menggunakan Physical Activity Scale for the Elderly (PASE), yang mengkatogerikan tahap PA sebagai sedentari, ringan, dan sederhana-ke-tinggi. Analisis statistik dijalankan dengan menggunakan perisian R versi 4.3.0. Daripada 831 peserta yang disaring, sejumlah 677 warga emas (purata umur 68.2 ± 6.0 tahun, 61.3% wanita)

diklasifikasikan sebagai tiada sarcopenia (n=58, 8.6%), possible sarcopenia (n=576, 85%), sarcopenia (n=25, 3.7%), dan severe sarcopenia (n=18, 2.7%). Keputusan menunjukkan bahawa peratusan wanita yang mengalami sarcopenia adalah lebih tinggi (5.8%, n=24) berbanding lelaki (0.4%, n=1). Secara keseluruhan, lelaki dan wanita yang mengalami sarcopenia serta severe sarcopenia mempunyai ketinggian yang lebih rendah serta lilitan lengan dan betis yang lebih kecil berbanding kepada mereka yang tiada atau mengalami possible sarcopenia. Kebanyakan lelaki dan wanita yang sarcopenia dan possible sarcopenia mempunyai HGS yang normal, tetapi prestasi kelajuan berjalan 4-m gait adalah rendah (<1.0 m/s). Kira-kira 54% peserta mempunyai tahap PA sederhana-ke-tinggi, tetapi tahap PA kelihatan menurun bila tahap keterukkan sarcopenia semakin meningkat. Analisis hubungkait menunjukkan bahawa umur, jantina, dan status pemakanan mempunyai hubungan yang signifikan dengan sarcopenia ($p<0.05$), tetapi bukan tahap PA. Analisis regression menunjukkan bahawa umur, jantina, status pemakanan, tahap PA, dan fungsi kognitif secara keseluruhan mempengaruhi risiko sarcopenia ($R^2 = 0.54$). Hasil kajian ini menunjukkan keperluan untuk intervensi awal melalui program-program senaman, pemakanan seimbang, dan sokongan penjagaan kesihatan berterusan bagi mengurangkan risiko sarcopenia dan kemerosotan kognitif dalam kalangan warga emas di Malaysia. (387 pp)

THE RELATION BETWEEN SARCOPENIA, PHYSICAL ACTIVITY, AND COGNITIVE FUNCTION IN COMMUNITY-DWELLING OLDER ADULTS IN MALAYSIA: A CROSS-SECTIONAL STUDY

ABSTRACT

This study examines the prevalence of sarcopenia among community-dwelling older adults in Malaysia and its association with cognitive function and physical activity levels. Community-dwelling older adults aged 60 y and above in high older persons ratio towns were recruited. Sarcopenia was assessed using the Skeletal Muscle Index (SMI), handgrip strength (HGS), and Short Physical Performance Battery (SPPB) based on the Asian Working Group for Sarcopenia (AWGS2) criteria. Participants were considered sarcopenic if they exhibited low muscle mass and strength/performance. Participants with all three low muscle mass, strength and performance criteria have severe sarcopenia while those with sufficient muscle mass but low strength or performance have possible sarcopenia. Cognitive function was assessed using the 1) Montreal Cognitive Assessment (MoCA) to screen for mild cognitive impairment, 2) Trail Making Test (TMT-A and TMT-B) to evaluate cognitive processing speed and flexibility, and 3) Digit Symbol Substitution Test (DSST) to assess information processing ability. Physical activity (PA) levels were measured using the Physical Activity Scale for the Elderly (PASE) that categorised PA levels as sedentary, light, and moderate-to-high. Statistical analyses were performed using R software version 4.3.0. From the 831 participants screened, a total of 677 older adults (average age 68.2 ± 6.0 y, 61.3% women) were classified as no sarcopenia (n=58, 8.6%), possible sarcopenia (n=576, 85%), sarcopenia (n=25, 3.7%) and severe sarcopenia (n=18, 2.7%). Results showed that a higher proportion of

women, 5.8% (n=24) were sarcopenic compared to men, n=1 (0.4%). Overall, sarcopenic and severe sarcopenia men and women were shorter in stature and have smaller arm and calf circumferences compared to those with no or possible sarcopenia. Most sarcopenic men and women have normal HGS but outcomes for the 4-m gait speed was poor (<0.9 m/s). About 54% participants engaged in moderate-to-high levels of PA, but PA levels declined with increasing sarcopenia severity. Correlation analysis showed that age, gender, and nutritional status were significantly associated with sarcopenia ($p<0.05$), but not PA levels. Regression findings showed that age, gender, nutritional status, PA levels, and cognitive function collectively influenced sarcopenia risk ($R^2 = 0.54$). These findings indicate the need for early intervention through exercise programs, balanced nutrition, and continuous healthcare support to reduce the risk of sarcopenia and cognitive decline in older Malaysian adults. (370 words)

CHAPTER 1

INTRODUCTION

1.1 Background of study

Physical and mental impairments are the conditions commonly related to ageing and may result in a loss of independence that would need constant care for daily living. Two types of geriatric conditions that are sarcopenia and cognitive dysfunction like dementia are examples of geriatric physical and mental impairments, respectively. These impairments contribute to huge financial expenditures, creating significant socio-economic and healthcare system burdens (Moon et al., 2016; Peng T. C. et al., 2020). Approximately 1.5% (USD $19.12 billion) of all direct medical spending in the United States was attributed to sarcopenia alone (Goates et al., 2019). Additionally, the total annual cost of GBP 2.5 billion was estimated to be spent in UK older adults with muscle weakness (Pinedo-Villanueva et al., 2018). Therefore, more studies are needed to understand and examine possible ways to manage these conditions.

In 2016, sarcopenia was officially recognized as a geriatric syndrome in the International Classification of Diseases (ICD-10-CM), code M62.84 (Anker et al., 2016). Sarcopenia is an age-related disease defined by progressive loss in skeletal muscle mass and function that results in multiple adverse outcomes, including physical disability, loss of independence, hospitalizations, burden in long-term care, and death (Tessier et al., 2022). Despite the clinical significance of sarcopenia, the assessment for sarcopenia and intervention programs are still uncommon in medical practices (Dent et al., 2021). Several consensus definitions have been developed to describe sarcopenia (Chen L. K. et al., 2020; Cruz-Jentoft et al., 2019). These definitions include a combination of factors like reduced muscle mass, impaired physical function (e.g., slow walking speed), and low grip strength (Anker et al., 2016; Dent et al., 2021; Larsson et

al., 2019; Merchant et al., 2021; Morley & Cao, 2015). While there are some overlaps in the individuals diagnosed using these definitions, their sensitivity and specificity in diagnosing sarcopenia differs based on the chosen criteria and cut-off points (Chen L.K. et al., 2016; Dent et al., 2021). For instance, the Asian Working Group for Sarcopenia (AWGS) emphasized that the cut-off values for sarcopenia are higher for individuals of Asian ethnicity compared to the European Working Group on Sarcopenia in Older People (EWGSOP) (Chen L. K. et al., 2014, 2020).

In both revised guidelines, AWGS2 and EWGSOP2 highlighted the need to determine low muscle mass in defining sarcopenia. Hence, both guidelines recognized the dual-energy X-ray absorptiometry (DXA) as reference method for muscle mass assessment but also endorse biological impedance analysis (BIA) as valid alternative tool, particularly in large-scale and community-based studies (Chen L. K. et al., 2020; Cruz-Jentoft et al., 2019). Although DXA offers high precision, it is costly, not portable and less feasible in large-scale and community-based setting. In contrast, BIA is more affordable, portable and practical for field assessments, particularly suitable for community dwelling older adults. Hence, in this study, BIA was used to measure muscle mass. Although BIA has some limitations such as susceptibility to hydration status, body temperature, and skin conductivity (Fang et al., 2020). Our researcher reduced these issues by following standardized procedures, such as encouraged the participant attended with fasting state, priority measurement of BIA first in the screening procedure, ensure room temperature stability, used the same model devices to ensure robustness of assessment.

The AWGS2 cut-points for grip strength in men and women are 28 kg and 18 kg, respectively (Chen L. K. et al., 2020), and for EWGSOP2, it was 27 kg for men and 16 kg for women (Cruz-Jentoft et al., 2019). For muscle mass, AWGS2 recommended

a cut off < 7.0 kg/m^2 for men and < 5.7 kg/m^2 for women, while EWGSOP2 suggested < 7.0kg/m^2 and < 5.5 kg/m^2 for women. Thus, the determination of sarcopenia depending on the consensus used for diagnosis.

Cognitive impairment is a condition that many people accept as normal deterioration of cognition due to aging (Harada et al., 2013). Early phases of cognitive deterioration are known as mild cognitive impairment (MCI). MCI is not dementia, the condition often notices as an intermediate stage between normal aging and dementia and is particularly linked to Alzheimer's disease (Nasreddine et al., 2005). Research indicates that approximately 10-15% of individuals with MCI progress to dementia each year, placing them at a significantly higher risk compared to the general population without MCI (Petersen et al., 2009, 2014). The transition from MCI to dementia is determined by the severity and extent of cognitive decline (McCollum & Karlawish, 2020). People with MCI may start to notice changes in certain functions, but they can take care of themselves and do their daily routine as usual (Harada et al., 2013; McCollum & Karlawish, 2020; Shim et al., 2020). A person with cognitive impairment has difficulty remembering, catching up on new information, focusing, or struggles with making decisions that impact their daily lives (Kumar et al., 2024). Notably, when MCI progresses into severe cognitive impairment that is dementia, and it negatively affects quality of life for the individual, their families and caregivers (Grabher, 2018). Severe cognitive impairment or severe dementia can lead to a person losing their ability to communicate verbally or in writing, making it difficult to live independently. They may also lose their ability to understand the meaning or importance of things and cognitive impairment may be severe enough to limit performing daily activities such as walking, lifting objects, and climbing stairs, and even eating or going to the washroom, ultimately leading to their total dependence on caregivers (McCollum & Karlawish, 2020).

The global economic burden of dementia continues to rise (Wimo et al., 2023). Worldwide, the cost for dementia is huge and is estimated to exceed USD $2.8 trillion in another 5 years (Lastuka et al., 2024). Researchers found that the average annual cost for family members with cognitive impairment may incur more than USD $10, where the expenses cover direct medical expenses, time and unexpected expenses and may also lower the quality of life for the entire family unit (Grabher, 2018; Nandi et al., 2022). According to a recent meta-analysis, researchers estimate that approximately 15% of community-dwelling older adults aged 50 years and older worldwide are affected by MCI (Bai et al., 2022). In Australia, the prevalence of cognitive impairment among individuals aged 65 and above ranges from 7.7% to 33.3% (Anderson et al., 2007; Low et al., 2004). While there is still no existing treatment currently to cure dementia-related cognitive impairment (Demurtas et al., 2020), non-pharmaceutical interventions remain a key approach in managing the conditions among older adults (Haque et al., 2025; Petersen et al., 2014). Similarly, Berg-Weger &Stewart (2017) also reported that non-pharmacological interventions as the primary approach to manage cognitive impairment symptoms and enhance well-being and quality of life (Berg-Weger & Stewart, 2017).

It is crucial to identify the stage of cognitive impairment if a person has a neurodegenerative condition, as these disorders are progressive over time, and the purpose of any treatment is to prevent, slow down, or stabilize the symptoms and functional decline (McCollum & Karlawish, 2020). To cope with the challenges arising from an ageing population, the government, businesses, and society should be prepared to adapt to the changing needs and structural demographics of ageing or aged nations (Asila Jalil, 2022).

Natural progression of aging is the main denominator of both sarcopenia and cognitive impairment. However, physical activity and exercise can reverse and even slow down the process of natural aging (Phoenix & Tulle, 2017; Tolea & Galvin, 2015; Zhang et al., 2023). Many studies found that sarcopenia and cognitive impairment are associated (Huang et al., 2016; Kara et al., 2020; M. Kim & Won, 2019; I. Lee et al., 2018). A systematic review and meta-analysis of 22 studies also reported that sarcopenia is associated with cognitive impairment (Peng T. C. et al., 2020). However, no specific subdomains of cognitive function such as processing speed, memory, attention or executive function were examined in the meta-analysis and it was not clear which condition presents itself first or they manifest at about the same time together. Factors such as physical activity (PA) and nutritional status were not adequately adjusted in the study. More importantly, the systematic review was looking at studies that defined sarcopenia using older guidelines as the most current and revised guidelines for EWGSOP2 and AWGS2 were published in 2019 and 2020, respectively.

Furthermore, previous studies were more focused on certain aspects of sarcopenia, such as muscle strength and performance concerning cognitive impairment while often excluding the measures of muscle mass which is the core component of sarcopenia diagnosis (Callisaya et al., 2015; Merchant, Goh, et al., 2021; Tolea & Galvin, 2015; Van Kan et al., 2012). Other possible risk factors that may influence both sarcopenia and MCI such as adequate physical activity and quality nutrition were not controlled for and explore in previous association studies between sarcopenia and cognitive impairment (Huang et al., 2016; Jiang et al., 2023; Tolea & Galvin, 2015; K. Zhang et al., 2023). As a result, the direction and complexity of the relationship between sarcopenia and cognitive decline remain unclear and need further investigation. Does having sarcopenia lead to decreased mobility and lessen social interactions and thus

lead, to cognitive impairment? Or does cognitive impairment lead to a future loss of muscle and strength from being less able to be independently mobile, and thus, leading to muscle weakness and loss? More studies and data are needed to elucidate the intricacies of these two conditions in relation to one another.

1.2 Problem Statement

Sarcopenia significantly impacts older adults' daily activities, functional ability, and limits mobility (Dent et al., 2021). Cognitive impairment is another major age-related health concern, ranging from mild cognitive impairment (MCI) to dementia, is similarly associated with increased risk of disability, reduced quality of life, and premature mortality. Evidence from longitudinal research suggests that sarcopenia and cognitive impairment can influence each other, whereby the muscle loss and reduced physical ability may lead to cognitive decline, while worsening cognition may accelerate muscle weakness and frailty (Chang et al., 2016; Peng et al., 2020). Both diseases shared underlying mechanisms, such as chronic inflammation, hormonal dysregulation, reduced physical activity, and impaired neural control of muscle function (Xing et al., 2023). The co-occurrence of sarcopenia and cognitive impairment amplifies the risk of adverse outcomes, including falls, hospitalization, and loss of independence, making it a critical public health concern .

Malaysia is projected to attain an aged nation status by 2030, with 15% of the population are aged 60 years and above, according to the Department of Statistic Malaysia (Abdullah et al., 2024). The growing number of older adults presents a significant challenge for public healthcare, as it leads to higher costs to meet their medical needs. Statistics show that the rise in the total dependency ratio is mainly driven by an increase in the old-age dependency ratio, which is projected to almost triple from

7.4 in 2010 to 21.7 in 2040 (Norazman et al., 2020). In 2017, Malaysia's total healthcare spending was estimated at RM57.36 million, accounting for 4.24% of the GDP, with a healthcare cost per person of RM1,790 (Norazman et al., 2020). Although specific spending on older adults is not reported, one study found that, on average, elderly Malaysians living in the community spent about RM426.50 per year on healthcare costs (Koris et al., 2019). This indicates that Malaysia will soon face substantial healthcare and socioeconomic challenges related to age-associated conditions. However the existing social and healthcare system in Malaysia are currently underprepared to handle the anticipated rise in the prevalence and associated economic burden of sarcopenia and cognitive impairment (Rosli et al., 2017). Furthermore, despite Malaysia is turning fast into an aged nation, there is still remain limited awareness, understanding, and clinical preparedness for effectively addressing these geriatric conditions within general clinical practice and public health sectors (Murukesu et al., 2019; Rosli et al., 2021).

Physical activity was well known to benefit both muscle health and cognitive function, may play a protective role in this relationship (Lenzen et al., 2023; Meier & Lee, 2020; Phoenix & Tulle, 2017; Taylor, 2014). However, most of existing studies have examined the interplay between sarcopenia, cognitive decline and physical activity mainly focused predominantly on Western populations (Cruz-Jentoft et al., 2019; Fielding et al., 2011; Kara et al., 2020; Marzetti et al., 2017; Petermann-Rocha et al., 2022; Vallejo et al., 2025). Research within Southeast Asia remain limited, especially in Malaysia where the culture practice, lifestyle, dietary habits, and healthcare system differ significantly from those in developed nations.

Thus, understanding the relationship between sarcopenia, physical activity, and cognitive impairment among older Malaysians is critical. Findings from this investigation will contribute valuable insights to guide targeted prevention strategies,

early diagnosis, and interventions for sarcopenia and cognitive impairment. This study's outcomes have the potential to inform clinical guidelines, optimize resource allocation, and enhance geriatric care practices, ultimately improving healthcare outcomes and promote healthier, independent, and higher-quality lives for Malaysia's ageing population.

1.3 Research Question

1. What is the prevalence of sarcopenia among community-dwelling older adults in Malaysia?

2. Is there an association between physical activity levels and sarcopenia among community-dwelling older adults?

3. Is cognitive function associated with sarcopenia among community-dwelling older adults?

4. Are physical activity levels and cognitive function associated sarcopenia among community-dwelling older adults?

1.4 Study Objective

1.4.1 Main objective

To investigate the relation between sarcopenia, cognitive impairment, and physical activity of community-dwelling older adults in Malaysia.

1.4.2 Specific objective

i. To identify the prevalence of sarcopenia in community-dwelling older adults in Malaysia.

ii. To determine the relation of self-reported physical activity level to sarcopenia in community-dwelling older adults in Malaysia.

iii. To assess the relation of sarcopenia to cognitive impairment levels in community-dwelling older adults in Malaysia.

iv. To explore the relationship of physical activity and cognitive impairment on sarcopenia in community-dwelling older adults in Malaysia while adjusting for potential cofounders such as physical activity and nutritional status.

1.5 Study Hypothesis

HO1: There is no significant relation between cognitive function and the prevalence of sarcopenia.
HA1: There is a significant relation between cognitive function and the prevalence of sarcopenia.

HO2: There is no significant relation between physical activity levels and the prevalence of sarcopenia.

HA2: There is a significant relation between physical activity and the prevalence of sarcopenia.

HO3: There is no significant relation between physical activity and cognitive function with the prevalence of sarcopenia.

HA3: There is a significant relation between physical activity and cognitive function with the prevalence of sarcopenia.

CHAPTER 2

LITERATURE REVIEW

2.1 Population Aging and Global Demographic Shift

Population aging refers to the phenomenon where the group of older adults become proportionally larger compared to the total population (Zucker & Bloom, 2023). This phenomenon is primarily attributed to the great progress of science and medicine that include improved nutrition, better living standards, and successful healthcare services, all of which positively impact on individuals' overall well-being and longevity (Azuar, 2022). The key issue is current low fertility rate and this demographic shift presents a larger burden on the healthcare system such as exceeding demands for medical services and the requirement for long-term care (Norliati et al., 2021). As life expectancy continues to rise, the aging population increases the absolute number of older adults at risk for sarcopenia and cognitive decline. It is important to address the challenges and healthcare needs associated with aging. Healthy aging will reduce the burden of older adults or delay as much as possible the functional disabilities that would result in needing constant care and higher medical assistance from other (Zucker & Bloom, 2023). The proactive steps to have healthy aging would be the investment that countries and individuals to minimise financial costs and dependency in older adulthood.

Aging is a natural process where the body's function deteriorates in different ways. Over time, the body undergoes various of changes from cellular, tissue, and organ levels, leading to a gradual decline in body system functions (Dent et al., 2018). It is important to note that while these changes are natural progressions, they are not uniform for every individual. This is because ageing related changes are reversible and they are closely related with lifestyle factors such as diet, exercise, and stress management that

would significantly influence the speed and extent of these age-related changes (Tinôco et al., 2023). Thus, although ageing is inevitable, how and rate of ageing is important and health maintenance, proper nutrition and effective exercises may each have a role to play for healthy ageing.

2.2 Understanding Sarcopenia and Its Impact on Older Adults

Skeletal muscle comprises about 40% of the body mass and made mostly from protein will tend to decline progressively with age (Volpi et al., 2004). Approximately 3-8% per decade after 30 y and accelerated decline of about 11% per decade after age 60 y are observed (Volpi et al., 2004; Wilkinson et al., 2018). Although it is expected that older adults experience some degree of muscle loss, people suffering with sarcopenia tend to lose muscle mass at a rapid rate as compared to those without the condition (Volpi et al., 2004). Skeletal muscle is capable in adjusting its size and function which influence by nutrition, hormones, physical activity and chronic disease (Brook et al., 2016; Frontera & Ochala, 2015; Kimura et al., 2018; Wilkinson et al., 2018). The rate of muscle mass loss in the upper limbs is half the rate of loss in the lower limbs (Janssen et al., 2000) and men experience greater age-related muscle loss than women (Kim et al., 2018). The prevalence of sarcopenia is about 5-13% of older adults aged 60-70 years old and in those age more than 80 y, the prevalence may be as high as 50% (Wilkinson et al., 2018).

The term “sarcopenia” was initially defined by Rosenberg in 1989 as a gradual and generalized reduction of muscle quality in terms of strength and mass that is associated with ageing (Rosenberg, 1997). The word sarcopenia is derived from the Greek words "sarx" (flesh) and "penia" (loss) (Rosenberg, 1997). It is a common and concerning issue particularly among the older population. Sarcopenia is a progressive

and age-related diseases which characterized by the loss of muscle mass, strength, and function (Tessier et al., 2022). It not only affects personal physical well-being but also has broader implications for overall quality of health outcomes (Baumgartner et al., 1998). The prevalence of sarcopenia is about 5-13% of older adults aged 60-70 years old and in those age more than 80 y, the prevalence may be as high as 50% (Wilkinson et al., 2018b). Sarcopenia represents a significant public health challenge as the global aging population are increasing.

In 2010, the European Working Group on Sarcopenia (EWGSOP) was the first to establish a standardized and comprehensive diagnostic framework which widely accepted measurement approach for sarcopenia diagnosis based on muscle mass, muscle strength and physical performance (Cruz-Jentoft et al., 2010). They changed the previous operational definition of sarcopenia with it included progressive and generalized loss of muscle mass as the first parameter to determine sarcopenia (Cruz-Jentoft et al., 2010). In 2018, EWGSOP updated the definition of sarcopenia that uses low muscle strength as the first parameter of sarcopenia diagnosis (Cruz-Jentoft et al., 2019). The group later modified its diagnostic standards for sarcopenia to emphasize the significance change of physical performance and published the guidelines as EWGSOP2 (Cruz-Jentoft et al., 2019). According to the revised guidelines of EWGSOP2, low muscle mass and strength are combined to confirm the diagnosis of sarcopenia, and its severity is diagnosed when additional physical performance is low (Cruz-Jentoft et al., 2019).

The two most used working group of operational criteria for sarcopenia seen in scientific publications today are the European Working Group on Sarcopenia (EWGSOP2) (Cruz-Jentoft et al., 2019) and Asian Working Group on Sarcopenia (AWGS2) (Chen L. K. et al., 2020). Definition of sarcopenia in AWGS2 and

EWGSOP2 are quite similar, with the slight difference where AWGS2 uses criterion cut-off points that are based on Asian population with special considerations such as comparatively smaller body size in measurements and anthropometry, different social or lifestyle variances, have greater adiposity, less mechanized and more physically active as compared to the Western population (Chen L. K. et al., 2020). Initially, AWGS defined sarcopenia as an "age-related decrease of muscle mass, plus low muscle strength, and/or low performance" (Chen L. K. et al., 2014). In 2019, AWGS revised the parameters where sarcopenia is diagnosed as low appendicular skeletal muscle mass (ASM) and low muscle strength with/without low physical performance as updated guideline AWGS2 (Chen L. K. et al., 2020).

Muscles are essential organs for daily movements and activities. Low muscle mass can result in reduced overall physical function and weakened muscles would lead to instability and balance issues. There are many studies indicating the low muscle mass increases the risk of falls, particularly in older adults (Hoogendijk et al., 2019). Loss in muscle mass is typically observed in older adults with sarcopenia, which are linked to morbidity and decreased strength because of a decrease in physical capacity in daily living (Kalyani et al., 2014; Larsson et al., 2019). The relatively low muscle mass might already have a negative effect to one's functioning skills and quality of life by limiting their ability to engage in enjoyable activities and subsequently leads to a loss of independence (Baumgartner et al., 1998; Buckinx et al., 2015). The consequence of sarcopenia is complex and extend beyond just simple muscle atrophy cause by malnutritional and or sedentary lifestyle (Dao et al., 2020). Thus, getting a bigger picture of the extent of sarcopenia rates in the community is important to stem the negative consequences of sarcopenia.

A systematic review and meta-analysis reported that the global prevalence of sarcopenia varied between 10% and 27% varying due to differences in classification criteria and cut-off points used across studies (Petermann-Rocha et al., 2022). However, in Asian studies, the prevalence of sarcopenia ranged from 5.5% to 25.7%, with a higher prevalence recorded in men, 5.1%–21.0% than in women, 4.1%–16.3%, (Chen L. K. et al., 2020). In Malaysia, the prevalence of sarcopenia in older adults ranged from 8.6% to 33.6% (Foo et al., 2023; Iskandar et al., 2021; Ramoo et al., 2022; Ranee et al., 2022). However, the variances from the prevalence rates may be due to the use of diagnostic criteria, such as those from the Asian Working Group for Sarcopenia (AWGS) and measurement tools and protocols. We need to ensure consistent identification and management of sarcopenia across populations to compare and understand sarcopenia prevalence in Malaysia.

2.3 The Role of Nutrition in Sarcopenia Development and Diseases Related Muscle Loss

Sarcopenia can also occur alongside with malnutrition (Bhattacharya et al., 2022; Brook et al., 2016; Cruz-Jentoft et al., 2019). This may result from low food intake, insufficient nutrient absorption due to natural age-related change in the body (Cederholm et al., 2017; Muscaritoli et al., 2010). Study had shown that older adults eat about 30% less food than when they were younger (Ahmed & Haboubi, 2010). Older adults experienced eating habit changes with age such as reduce in appetite due to denture problem, less sensitivity in taste and smell, slow digestion, lower physical activity in daily activities, and some cause by financial issue, loneliness without accompanied when having meal and some appetite change were caused by the side effect of on-going medication (Hedman et al., 2016; Maafs-Rodríguez & Folta, 2023).

There is substantial evidence support the roles of dietary protein as key anabolic stimuli for muscle protein synthesis (Landi et al., 2016; Rogeri et al., 2021). An intervention study found that 12 weeks of high consuming protein help older adults to gain muscle quality in mass and function (Malafarina et al., 2021). Poor nutrition particularly inadequate protein intake is a major key contributor to sarcopenia (Bhattacharya et al., 2022).

In recent years, many researchers found that current recommended dietary allowance (RDA) state that protein (0.8g/kg/day) is not enough for older adults as deteriorate of muscle quality cause by aging (Delmonico et al., 2009; Landi et al., 2016). For vulnerable older adults' population, higher RDA and appropriate protein intake is vital for growth and preservative of muscular homeostasis (Landi et al., 2016). Apparently, for maintaining muscle health during the aging process, it is advisable to consume more daily protein (1.0-1.2g/kg/day). However, in cases of older individuals who are dealing with acute or chronic health conditions, a slightly higher (0.4-0.7g/kg/day) than RDA of protein intake might be necessary. If older adults are suffering from severe illness or malnutrition, they might require as much as 2.0g of protein per kilogram of body weight daily (Bauer et al., 2013; Landi et al., 2016; Malafarina et al., 2021; Veronese et al., 2019).

Sarcopenic older adult can lead to increased frailty, loss of mobility, and greater susceptibility to falls and fractures (Kim & Won, 2019). Sarcopenia was common in older adult with fragility fractures or osteoporosis (Landi et al., 2017). The prevalence of osteoporosis was found to grow with the severity of sarcopenia, and having osteoporosis was associated to an increased risk in developing sarcopenia (Wong et al., 2019). Frailty is characterized by a deterioration in the performance of several physiological systems, as well as an increased vulnerability to stressor such as acute

illness or trauma, resulting in physiological decline (Landi et al., 2017), which increases the risk of adverse outcomes from sarcopenia (Hoogendijk et al., 2019). Older adult who are fragile have trouble on doing independent tasks, referred to functional incompetence (Murukesu et al., 2019).

Skeletal muscle also known as the largest major organ for storage of glucose after digested through an insulin dependent mechanism (Kalyani et al., 2014). Sarcopenia have a profound impact on metabolic health, as it is associated with insulin resistance, glucose metabolism abnormalities, and an increased risk of obesity and Type 2 diabetes (Hong & Choi, 2020; Z. Xu et al., 2022). Studies found that individual with diabetes and obesity which consequently impact in glucose transport and metabolism process that are closely mask to sarcopenia (Wang et al., 2020; Z. Xu et al., 2022). The pathogenic inter-relationship between adipose tissue and muscle is also crucial in sarcopenia and contributes to functional and physiological impairment (Wang et al., 2020).

Another overview from Marzetti and colleagues highlighted several influencing factors on sarcopenia, including (i) individual factors like age, early life events, genetics, and low birth weight, (ii) hormonal changes, inflammation, and mitochondrial dysfunction, (iii) lifestyle habits such as poor diet, inactivity, alcohol and tobacco use, and (iv) chronic conditions, including cognitive decline, diabetes, and advanced organ disease (Marzetti et al., 2017). However, chronic illness such as cancer, chronic kidney disease, heart failure and inflammatory pathways lead to more severe form of muscle loss is known as cachexia (Kalyani et al., 2014; Thomas, 2007).Understanding the mechanisms between age-related and muscle related muscle loss is critical to develop effective nutritional, medical and intervention strategies.

2.4 Assessment of Sarcopenia in Older Adults

The severity of sarcopenia is defined by using AWGS2 diagnostic criteria outlined in participants aged 60 years and above (Chen L. K. et al., 2020). According to the guidelines, "possible sarcopenia" is defined as either low muscle strength or low physical performance. When there are both low muscle mass with either low muscle strength or low physical performance, the participant is diagnosed as “sarcopenic”. “Severe sarcopenia” is defined when participants met all the criteria of low muscle strength, low muscle mass, and low physical performance (Chen L. K. et al., 2020). Participants meeting none of the three criteria were classified as “no sarcopenia” (Chen L. K. et al., 2020).

2.4.1 Muscle Mass

Aligned with AWGS2 diagnostic framework, muscle mass is the primary component for diagnosing sarcopenia, as it reflects the structural foundation of skeletal muscle health. The AWGS2 provides method specific cut-off points for low muscle mass to account for differences in measurement principles between techniques. For dual-energy X-ray absorptiometry (DXA), low muscle mass is defined as appendicular skeletal muscle mass (ASM) divided by height squared (ASM/height^2) of < 7.0 kg/m^2 for men and < 5.4 kg/m^2 for women. Whereas, for bioelectrical impedance analysis (BIA), the corresponding cut-off values are slightly higher: < 7.0 kg/m^2 for men and < 5.7 kg/m^2 for women reflecting systematic differences in estimates between the two methods (Chen L. K. et al., 2020). DXA is the reference method for muscle mass assessment, which used low-dose X-rays to quantify lean tissue, fat, and bone mass with high precision. However, its requirement for specialised equipment limits its use in large-scale field studies.

In this study, muscle mass was assessed using bioelectrical impedance analysis (BIA) with the Bodystat Quadscan 4000 device. Bodystat BIA estimates body composition from the electrical resistance (impedance) of body tissues at multiple frequencies (5, 50, 100, and 200 kHz), allowing for the estimation of body composition by estimating fat-free mass (FFM), lean mass and other body composition based on the conductive properties of body water (Fang et al., 2020; Kyle et al., 2004). Variations in total body water (TBW), particularly shifts between extracellular and intracellular compartments, significantly influence impedance values. The underlying principle of BIA is based on the theoretical model: $V = \rho Ht^2 / R$ (Kyle et al., 2004), where V represents the conductive volume (assumed to correspond to TBW, ρ is the resistivity of the conductor, Ht is the height of the individual, and R is the measured whole-body resistance. Since biological tissues conduct electricity at different degrees, the model assumes that TBW is directly proportional to Ht^2 / R, making this index a key determinant of conductive volume (Kyle et al., 2004).

Although BIA is portable, non-invasive, and practical for community settings, though more sensitive to hydration status, recent food intake, and measurement conditions. Hence, the increased hydration or fluid retention can affect the result in underestimation of fat mass and overestimation of lean mass, while dehydration may produce the opposite effect (Evans et al., 2018). Therefore, stable hydration status and consistent measurement conditions are critical to ensure valid and reliable BIA results.

2.4.2 Muscle strength and physical performance

The measurement of hand grip strength (HGS) is used to determine the overall muscle strength and is a valid and reliable indicator of muscle health in older adults (Reijnierse et al., 2017). Low HGS was reported as a key characteristic to determine the

initial muscle health of older adults (Franzon et al., 2019). The Short Physical Performance Battery (SPPB) is used to evaluate the lower extremity function of older adults that are highly correlated to daily life activities such as stair climbing and walking in older adults (Guralnik et al., 1994). It is also used as a screening tool to provides prognostic information to identify the early identification of lower extremity decline in older adults that can help to delay disability in aging population (Guralnik et al., 1994; Zhang et al., 2019). The SPPB consists of the evaluation test of functional assessment in total of 3 subtests such as standing balance, a timed 4-m walk at flat surface, timed test of five repetition sit to stand from a chair (Ack et al., 1995). Each subtest is scored 0-4, and the total score of SPPB is 0-12. SPPB score $\leqslant$ 9 indicate low muscle performance in guideline AWGS2. The validity and reliability of this scale had been analysed and established that the scale score is significant associated with the risk of disability and mortality (Ack et al., 1995; Guralnik et al., 1994). For instance, a lower SPPB score indicates relatively low performance that predicts several negative outcomes, including lower quality of life, decreased mobility, functional disability, and mortality (Freiberger et al., 2012). Thus, it is a useful tool as a predictor of functional dysfunction in community-dwelling older adults as it easy and require minimal time and equipment to administer.

2.4.3 Epidemiology and Consequences of Sarcopenia

Age-related muscle mass loss may increase the risk of falls due to poor body balance from weakened muscles and a fall may lead to premature death (dos Santos, Cyrino, et al., 2017). A recent meta-analysis by Yeung and colleagues that included 33 studies with total of 45,926 individuals found that sarcopenic individuals have a 60-89% fall risk and 71-84% fracture risk compared to those without the condition (Yeung et al., 2019). This showed that having sarcopenia significantly increases the likelihood

of falls. Grimmer and colleagues (2019) reported a significant increase in fall-related mortality among older adults aged 65 to 90 years, with the risk increasing sharply from one death per 10,000 falls to 40 deaths per 10,000 falls, representing 4000% increase. This substantial and alarming rise in the mortality rate indicates the urgent need for effective fall prevention strategies and interventions to promote healthy ageing (Grimmer et al., 2019). Progressive loss in muscle mass and muscle strength are associated with adverse health consequences in older adults (Cruz-Jentoft et al., 2019; Dam et al., 2014; Studenski et al., 2014), including decreased physical independence, impaired cognitive function, and heightened risk of comorbidities and mortality (Aarden et al., 2021; Gustafsson & Ulfhake, 2021; Kohara et al., 2017; Moisey et al., 2013).

Growing evidence showed that assessments of muscle mass and strength is a crucial step for clinicians to determine the health of older adults and to improve their overall well-being (Srikanthan & Karlamangla, 2014). By measuring muscle mass and strength, clinicians can detect the early signs of muscle loss and subsequently address methods to prevent frailty and reduce other health risks (Cao et al., 2022; Li et al., 2018). Regular assessments help to identify sarcopenia, allowing for interventions such as personalized nutrition plans and strength training to maintain muscle function (Nishimoto et al., 2024). Stronger muscles improve balance, mobility, and independence, and also reduces the risk of fall and injuries (Lenzen et al., 2023; Tey et al., 2021). By preserving muscle mass and strength, older adults can maintain their physical function, quality of life and overall maintain their own independence.

However, assessing muscle mass accurately is not easy to conduct in every health centre as it requires huge or expensive devices. Clark and Manini (2008) proposed a conceptual approach that separates the age-related decline in skeletal muscle

mass from the decline in muscle function (Clark & Manini, 2008). Furthermore, a longitudinal study found that the reduction in muscle strength in the older adults occurs at a rate of 2-5 times more rapidly compared to the decrease in skeletal muscle mass (Mitchell et al., 2012). They highlighted that losing muscle function is a more adverse outcome for health problems and physical independence compared to loss of muscle mass (Chen W. L. et al., 2015; Clark & Manini, 2008; Mitchell et al., 2012). Consequently, the better solution would be to track muscle strength as it is much easier and more practical than measuring muscle mass in clinical and healthcare settings.

2.5 Aging-Related Sarcopenia and Cognitive Function

In aging population, cognitive domains (memory, attention, executive function) often decline, and emerging evidence links to concurrent losses in muscle mass and strength. Sarcopenia has been linked to age-related cognitive health issues, and both of these conditions together lead to higher risk of morbidity and mortality (Sui et al., 2021). Both conditions have significant implications for negative health-related events that affect an individual's overall well-being and quality of life (Gao et al., 2024). The literature that investigated on these two health issues together is sparse. Interestingly, there is a notable overlap between sarcopenia and cognitive function in older adults, sharing common risk factors and pathophysiological pathways. Several studies found that sarcopenia and cognitive function have common pathogenesis pathways indicating there is potential link between muscle and mental health in older adults (Beeri et al., 2021; I. Lee et al., 2018; Peng T. C. et al., 2020; Scisciola et al., 2021). The exact mechanism pathogenesis of sarcopenia is still unclear.

Aging is the highest risk factor contributing to both sarcopenia and cognitive impairment. Some studies have reported that individuals with sarcopenia may have an

increased risk of experiencing cognitive decline and physical impairment (Beeri et al., 2021; Du et al., 2023; Tolea & Galvin, 2015). On the other hand, studies reported that cognitive impairment in advance can induce physical inactive, appetite loss and at the same time increased sedentary behaviour, which potentially contributes to the development of sarcopenia (Hartman et al., 2018; Kimura et al., 2018; Ogawa et al., 2018). This bi-direction interaction and relationship between the two conditions highlights the possible interconnection of both muscle health and cognitive function in geriatric health and care. However, clinical studies presented that as the underlying mechanism is still unclear and the current lack of study limits the justification on medical interventions and advancements to treat (Beeri et al., 2021). Both sarcopenic and cognitive impairment together were found to be associated with higher rates of death, hospitalization, and falls, as well as admission to long-term care facilities (Buckinx et al., 2015). Hence, determine the relation of sarcopenia and cognitive impairment is vital in the context of an aging global population.

Other studies of older adults who have sarcopenia detected that at the same time were at risk of experiencing cognitive decline (Chang et al., 2016). However, there may be some conflicting results in previous studies as sarcopenia were defined and measured differently due to the earlier versions of guidelines from EWGSOP and AWGS (Sui et al., 2021). Cipolli and researchers reported that individuals with sarcopenia were found to be over twice as likely to experience cognitive decline compared to those without the condition (pooled OR = 2.50, 95% CI: 1.26–4.92; p = 0.008) (Cabett Cipolli et al., 2019). Despite high variability across studies (I^2 = 84%), the findings highlight the importance of early identification and management of sarcopenia as a potential strategy to reduce the risk of cognitive impairment in ageing populations (Cabett Cipolli et al., 2019). Another recent systemic review and meta-analysis, researchers found that the

link between sarcopenia and cognitive problems is consistent, independently on the method they defined sarcopenia or the severity of cognitive decline (Peng T. C. et al., 2020). Peng and colleague's also reported that older adults with sarcopenia are about 2.2 times more likely to have cognitive decline. The evidence suggests a strong association between sarcopenia and cognitive impairment among older adults.

Studies also reported that weaker quadriceps and handgrip strength (HGS) were also significantly connected to cognitive impairment (Chen W. L. et al., 2015; Van Kan et al., 2013). Another cross-sectional study conducted over a total number of 1,799 participants aged 60 years and older found that stronger leg muscles were linked to better performance in the Digit Symbol Substitution Test (DSST) that measures spatial awareness and motor speed (Chen W.L. et al., 2015). The researchers suggested that muscle strength is associated to the frontal lobe of the brain that responsible for decision-making and other high-level functions based on their findings (Chen W. L. et al., 2015). Another study with 555 participants, participants aged 85-89, showed that better cognitive performance were associated with lower handgrip strength (Taekema et al., 2012). While muscle degeneration is considered a predictor of cognitive decline, the connection between muscle mass and cognitive problems is not always clear and consistent (Sui et al., 2021).

Aging plays an important role in both degeneration of musculoskeletal and cognitive function. Even though the exact reasons are not completely defined, there might be some risk factors that explain why older adult with sarcopenia have cognitive decline. There seems to be a connection between the muscles and the brain, especially when people exercising the muscles release substances called myokines, and these can transmit impulses to the brain (Scisciola et al., 2021). Physical activity helps maintain brain functions and improve the process of neurological diseases (Choi et al., 2024). It

also encourages muscle cells to produce and release these myokines (Gao et al., 2024). There may be a direct interaction between muscles and the brain when it comes to cognitive health (Liu et al., 2024).

2.6 Mild Cognitive Impairment and Dementia in Older Adults

The brain central nervous system (CNS) plays a critical role in cognition and mobility. Cognitive function is referred to how our brain works to understand things, remember information, learn new things, focus on tasks, make decision, and use language in daily life (Harada et al., 2013). It includes the ability on different aspects like how we see and sense the world, how we remember things, learn, and pay attention (Harada et al., 2013). In Malaysia, prevalence rates can vary between 22.4% and 68%. (Khairiah et al., 2016; M Zapawi et al., 2024). Another recent study reported the prevalence of MCI of 18.7% among older Malaysian adults age 50 y and above, with the majority of individuals showing poor control of comorbidities (Atri Roop et al., 2025).

MCI is defined as a preclinical state of brain disorder that is a transitional zone between normal cognitive function and clinically probable Alzheimer's disease (AD) (Petersen et al., 1999; Winblad et al., 2004). MCI may affect Instrumental Activities of Daily Living (IADL) minimally and is not severe enough to interfere significantly with any daily function and independency (Petersen, 2004). The symptoms for individuals who experience MCI may be forgetfulness, find it hard to make decisions, difficulty in follow instructions and unable to pay attention for longer periods at a time. Mostly, friends or family members who stay close to them will notice the symptoms of people with MCI. MCI may have consequences such as depression, lack of interest with surrounding matters, become anxious and short tempered without provocation. MCI is