Review

Chronic Kidney Disease and Sarcopenia: A Qualitative Review of the Role of the Psoas Muscle Measurement

Song ah Chai , Sameena Zabin Iqbal * , Darius Lazarus , Celena Scheede-Bergdahl

Posted Date: 9 April 2026

doi: 10.20944/preprints202604.0701.v1

Keywords: psoas muscle; CKD; sarcopenia

 doi:10.20944/preprints202604.0701.v1

Review

Chronic Kidney Disease and Sarcopenia: A Qualitative Review of the Role of the Psoas Muscle Measurement

Song ah Chai [1], Sameena Zabin Iqbal [1,2,*], Darius Lazarus [3] and Celena Scheede-Bergdahl [1]

[1] McGill University, 845 Rue Sherbrooke O, Montréal, QC H3A 0G4, Canada
[2] NDG Medical Centre, 4170 Bd Décarie, Montréal, QC H4A 3K2, Canada
[3] CISSS Outaouais Gatineau, 80 Av. Gatineau, Gatineau, QC J8T 4J3, Canada
* Correspondence: sameena.iqbal@mcgill.ca

Abstract

Chronic kidney disease (CKD) is a common medical condition seen in North America, ranging between 10-12% of the general population, which has significant impact on health care costs and patient survival [1]. Sarcopenia is often seen in between 2.8% to 75% in the CKD population based on the method of measurement and definition chosen to report [2–8]. This qualitative review of the literature for sarcopenia in CKD will focus on the utility of the Psoas muscle measurement. Psoas muscle measurement is a surrogate method to quantify muscle mass and its advantages and disadvantages as a choice for utilization in the sarcopenia definition is explored with the different diagnostic frailty scores published. The role of different comorbidities within the CKD population is further explained in the context of muscle mass measurement and the associated clinical outcomes. The ability and relevance of longitudinal use of muscle mass assessments in the clinical context will be emphasized on clinical evaluation of the CKD patient and follow up nutritional and physical training requirement to rebuild and maintain muscle mass.

Keywords: psoas muscle; CKD; sarcopenia

1. Introduction

Chronic kidney disease (CKD) has a prevalence of 10-12% in the North American population and imposes a significant burden on medical costs and mortality. [1] Sarcopenia, a chronic, age-related condition characterized by the loss of skeletal muscle mass and function, is highly prevalent in CKD patients. This condition leads to decreased quality of life, impaired performance in daily activities, and an increased risk of morbidity. [8] When sarcopenia is defined as lower muscle mass, strength and/or performance, the prevalence of this condition in the chronic kidney disease population ranges between 2.8-75 percent depending on the measurement chosen and the severity of CKD Grade level. [2–9]

The sarcopenia observed in the CKD population is postulated to result from a chronic inflammatory state coupled with poor nutritional parameters. Furthermore, metabolic acidosis—a complication often seen in the later stages of CKD—is associated with muscle wasting. At the molecular level, this catabolic state is primarily mediated through the activation of the ATP-dependent ubiquitin-proteasome pathway, which accelerates protein degradation and diminishes protein synthesis. [10]

Psoas muscle measurement is a surrogate for skeletal muscle mass estimation and has been utilized in the literature to assess presence of sarcopenia. This qualitative review intends to describe the research use and impact of the psoas muscle measurement tool in the CKD population for utility in sarcopenia diagnosis and associated clinical outcomes, which predict the clinical prognosis. [11,12]

 doi:10.20944/preprints202604.0701.v1

2. Definition of CKD

CKD is defined as an anatomical, pathological or clinical diagnosis of renal disease for 3 months or more in duration. Anatomical abnormalities are diagnosed by renal imaging, whereas pathological anomaly is diagnosed through renal biopsy. [13] The clinical diagnosis is derived from urinalysis and estimated glomerular filtration calculation using a standardized equation either CKD epi or Cockcroft Gault. The five grades of CKD are as follows: >90ml/min/1.73m2, 60 to 89 ml/min/1.73m2, 45-59 ml/min/1.73m2, 30-44 ml/min/1.73m2, 15-29ml/min/1.73m2 and less than 15 ml/min/1.73m2, Grades 1, 2, 3A, 3B, 4, and 5 respectively. [13] Further categorization of CKD is quantified with an additional albuminuria classification of A1, A2, A3 with normal, microalbuminuria and overt proteinuria.[14]

3. Definition of Sarcopenia

The term "sarcopenia" was coined by Irwin Rosenberg in the late 20th century to describe age-related skeletal muscle loss. While the concept appeared simple, the coexistence of chronic disease in 92% of aging populations necessitated more nuanced descriptions. [15] Consequently, health organizations adopted the definition to include any loss of muscle tissue and function resulting from aging, disease, nutritional deficiencies, or inactivity. [15] A simple method to describe the degree of sarcopenia is shown in Table 1, based on the reduction in either one component of muscle mass or strength or both. The components of sarcopenia measurements are summarized in Table 3.

Older age alone is recognized as a cause for sarcopenia, and its prevalence has been documented as high as 22.6% in older adults within the general population.[16] Increased healthcare costs are attributed due to the morbidity and mortality associated with sarcopenia. As the population ages, muscle mass decreases from 3-8% per decade after the age of 60. [17] A decrease in muscle mass often is accompanied with diminishing muscle strength and quality of life (QoL). With lower muscle functionality, the risk for falls and loss of independence increases, which ultimately contributes has shown to elevations in hospitalization rates and mortality. [18] Age-related muscle mass loss tends to be mediated through age-related chronic low-grade inflammatory profile (CLIP), resulting in an inflammatory process that increases muscle fibre loss and scarring [19,20].

One of the first organizations to propose a definition and guideline for sarcopenia was the EWGSOP (European Working Group on Sarcopenia in Older People) in 2010. [21,22] Its guidelines are amongst the most widely used, with over 3400 citations, including about 2600 original articles in the Web of Science database [21]. EWGSOP defined sarcopenia as low skeletal muscle mass and strength using different measurement techniques as noted in Table 4. EWGSOP-defined sarcopenia has been related to several adverse clinical outcomes, such as loss of mobility, falls, osteoporosis, fractures, physical frailty and disability, poor quality of life, loss of independence and mortality [21].

The updated version of EWGSOP known as the EWGSOP2 describes sarcopenia is only based on low skeletal muscle mass and strength, whereas physical performance is no longer required for the definition. Sarcopenia disease severity is described with the new definition. Cut off points have also been included for standardization. In a prospective observational study conducted by Yang and colleagues further investigated the differences and showed higher sensitivity in EWGSOP2 than its counterpart. The updated definition also showed higher performance for falls prediction and hospitalizations [21].

In 2014, the FNIH (Foundation for the National Institutes of Health) Sarcopenia Project recommended a new set of criteria and standardized cut off scores for low muscle mass and low grip strength based on data derived from a large, pooled dataset of an elderly population. [22] Their decision was to adjust appendicular lean mass (ALM) and grip strength for body mass index to decrease sources of error. [23] A study by Schaap and colleagues decided to further investigate sarcopenia defined by the EWGSOP and the FNIH. In their observations, two sarcopenia definitions used by FNIH were applied: First, a disease characterized by the degree of lean mass and grip strength. Second, the degree of lean mass, muscle strength and quantity of the gait speed. The

 doi:10.20944/preprints202604.0701.v1

researchers recommended to investigate the following: (a) the associations between sarcopenia as defined by EWGSOP and FNIH definitions and the incidence of recurrent falls and fractures, and (b) the association between the underlying components of these sarcopenia definitions (degree of lean mass, muscle strength, and quantity gait speed) and the incidence of recurrent falls and fractures. Researchers claimed that there were no significant associations between both groups and that the lower cutoff values of the FNIH criteria might have been too strict. Also, researchers concluded that a low grip strength was associated with incidence falls, independent of the degree of lean mass and quantity of the gait speed.[22]

Age is a known risk factor for sarcopenia, the SCWD (Society for Sarcopenia, Cachexia and Wasting Disorders) reported that the aged population is a requirement of diagnosis of sarcopenia. Other groups are at risk such as individuals with diabetes mellitus (DM), who have an accelerated loss in muscle mass and strength, eventually leading to sarcopenia diagnosis at a much younger age. [24]

Despite their differences, sarcopenia defined by the EWGSOP, the SCWD and the FNIH (Foundation for the National Institutes of Health) have all been validated as screening tools and longitudinal testing to diagnose sarcopenia. [24] Multiple definitions of a medical condition occurs because the associations rely on their expert opinion specific to the populations they serve.

As researchers tried to better understand and quantify sarcopenia, muscle functionality has been determined via hand grip strength and gait speed to define sarcopenia. Several reasons called for the addition of strength evaluation to muscle mass measurements. It is accepted that decreases in muscle mass would result in diminish muscle function. Muscle morphology can change due to infiltrative disease or fat content and in turn reduce muscle function. Hence, the addition of new criteria of muscle morphology will allow a more comprehensive understanding of muscle tissue. The hand grip assessment quantifies upper body muscle strength, as the measurement quantifies the recruitment of muscle fibres in contraction, especially the fast-twitch type IIa fibers, whereas, gait speed is a method that evaluates muscle performance and endurance.

The potential disadvantage of the addition of physical functionality components in a definition of sarcopenia include the decrease in the physical activity performance of the subject is not the result of muscle function such is documented in cases of excessive pain syndromes, rheumatological conditions with decrease range of motion or neurological disorders that ultimately will decrease muscle mass due to immobility. Other examples of such medical conditions are volume overload, arthritis, carpal tunnel syndrome, cerebrovascular disease, peripheral neuropathy, etc. The current sarcopenia definitions also do not include the fat distribution in muscle compartments, subcutaneous or visceral fat, or other infiltrative conditions such as sarcoidosis, and amyloidosis. [82–85]

Table 1. Diagnosis of Sarcopenia by Muscle strength and mass, muscle performance measures not required [30,32].

Muscle Strength	Muscle Mass	Sarcopenia scale
Normal	Normal	Normal
Low	Normal	Low
Normal	Low	Low
Low	Low	Severe

 doi:10.20944/preprints202604.0701.v1

Table 2. Prevalence of sarcopenia among CKD Populations.

Author	Study design	Definition	Study population	Method	Sarcopenia Prevalence
Isikawa et al. 2018	Cross sectional study	AWGS	CKD Grade 3-5	Skeletal Mass index	25%
Moreno-Gonzalez et al., 2020	Cross sectional study	EWGSOP2	CKD Grade 1-4	BIA, handgrip, SPPB	9.3-16.8%
Harade et al. 2017	Cohort study prospective	Low muscle mass	CKD Grade 3-5	PMI	41%
Duarte et al. 2024	Meta-analyses	Low muscle mass, strength and performance	CKD Grade 3-5	EWGSOP2, EWGSOP, FNIH, AWGS	0.5 -75% Mean 24.5%
Roshanravan et al. 2013	Cohort study prospective	Low muscle performance	CKD Grade 2-4	TUG	31% with slow TUG
Jeong et al. 2019	Prospective Cohort	EWGSOP	CKD Grade 3-4	BIA	19.6%
Souza et al. 2017	Prospective Cohort	EWGSOP FNIH	CKD Grade 2-5	DXA	Grade 2-3A 34.5% Grade 3B-5 65.5%
Kim et al., 2014	Observational cross sectional study	EWGSOP	ESRD	BIA, handgrip	33.7%
Foley et al., 2007	Third National Health and Nutrition Examination Survey	Janssen et al., 2000	CKD Grade 1-5	BIA for skeletal mass index	3 .8-50.7%

Table 3. Sarcopenia components to measure and apply in CKD.

Measurement	Measurement Methods	Guideline Definition component	Application in CKD
Muscle strength	Hand grip	(F)NIH, EWGSOP(2)	Yes
	Isometric testing of knee flexion/extension		Yes
Muscle mass	ALMI Appendicular lean mass	(F)NIH, EWGSOP(2), IWG, SCWD	Yes
	ASMI Appendicular skeletal muscle index	(F)NIH, ESPEN (SIG), EWGSOP(2), IWG, SCWD	Yes
	Bioimpedence Analysis		
	Total skeletal mass	EWGSOP2, AWGS, IWGS	Yes
	Psoas muscle area	Surrogates but not measured for guidelines	
	Thigh muscle mass		Yes
Muscle Performance	Gait Speed	IWGS, (F)NIH, EWGSOP(2), ESPEN(SIG), EWGSOP(2)	Yes
	Time up and Go		Yes
	Six minute walking distance		Yes

 doi:10.20944/preprints202604.0701.v1

AWGS: Asian Working group for Sarcopenia (2025). [25], IWGS: International Working group for Sarcopenia (2011). [26], (F)NIH: Foundation of the National Institute of Health (2017). [27]

EWGSOP(2): European Working Group for Sarcopenia in Older People (2019). [28], EWGSOP: European Working Group for Sarcopenia in Older People (2017). [29], ESPEN(SIG): European society for Clinical Nutrition and Metabolism (Special interest Groups) 2009. [30]

4. CKD and Sarcopenia

There is a wide range of sarcopenia prevalence associated with CKD from 2.8% to 75% based on the CKD grade, presence of other comorbidities, age and body mass index. [6] Table 2 reports the different cohort and cross-sectional studies that describe the prevalence of sarcopenia is this context. The variation in the prevalence is further caused by the type of method to measure muscle mass and the burden of medical illness in the population. The prevalence increases incrementally with each progressive Grade of CKD. The trend of the incremental change was not found statistically significant even though the prevalence of sarcopenia using skeletal muscle mass index in one study was described as follows: for stage 3a is 17%, stage 3b is 20%, stage 4 is 29%, and stage 5 is 38%. [31]. Similarly, in the study by Moreno-Gonzalez, the prevalence of sarcopenia using bioelectrical impedance analyses was reported as 9.8% among the Grade 1 and 2 CKD subjects and 14.2% among the Grade 3 and 4 CKD subjects. [3]. The prevalence of obesity associated sarcopenia was measured to be higher among the dialysis population reported as 50% compared to the non-dialysis population with a prevalence of 19.6%. [2]

5. Pathophysiology of Sarcopenia in CKD

Sarcopenia occurs when there is increase muscle tissue catabolism and lower myogenesis affecting muscle growth, regeneration and protein synthesis within the skeletal muscle system. The pathophysiology is associated with inflammatory state of chronic disease which is characterized by higher Interleukine 6 (IL6), Interleukine 1 beta (IL 1 beta), Interleukine 1 Receptor Antagoist) IL1 RA, Interleukin 10 (IL10) and Tumor Necrosis Factor alpha (TNF alpha) serum concentrations. [32] Increased oxidative stress up-regulates the inflammatory markers in aging, which results in higher levels of cytokines in particular IL1, TNF alpha and IL6 in the setting of poor nutritional status. [32] The proinflammatory gene up-regulation is further potentiated by hypoxia and hypoglycemia. [32] Higher rates in protein catabolism and decreased protein synthesis have been shown to be associated with these inflammatory markers, further impacting on the nutritional state. [32]. There is also increased myostatin expression, decreased sclerostin and Follistatin levels, decrease VEG-F, IGF-1, FGF levels, and increase in FGF 23 levels associated with hyperparathyroidism.[33]. Vitamin D deficiency, testosterone deficiency, decreased growth hormone levels and insulin growth factor 1 contribute further to the maintenance of sarcopenia.[33]

6. Psoas Muscle as a Measurement of Sarcopenia in CKD

There are different methods of measurement reported in the literature to utilize for diagnostic purposes of sarcopenia. Certain methods of measurement have been described to evaluate the lean muscle mass, but two commonly used and often preferred means are dual X-ray absorptiometry (DXA) and bioimpedance analysis (BIA). [34] Although both methods have been used in the clinical setting, DXA is preferred over BIA, because BIA has a tendency to overestimate muscle mass. [35,36]. Both methods are shown to have high concordance but DXA is more reliable with less bias error. The use of BIA is favoured over DXA because of the lower cost, user-friendliness, and no radiation exposure, which could all be concerns for geriatric populations. [37] There is also other research emerging further investigating other measurement tools, such as using 3D ultrasound techniques, also shown to measure sarcopenia in geriatric populations, another potential portable device to be applied easily for longitudinal care and muscle mass monitoring. [38]. While DXA remains a traditional gold standard for measuring sarcopenia, its requirement for specialized equipment often

 doi:10.20944/preprints202604.0701.v1

limits its use in routine clinical surveillance. Consequently, researchers have begun to evaluate the cross-sectional area of the psoas muscle as a potential representative of whole-body skeletal mass in CKD patients.

The simpler method described to quantify muscle mass is the measurement of the cross-sectional area of the psoas muscle (PMA), on a CT scan or MRI image at the L3 or L4 level. The psoas is a long fusiform-shaped muscle that lines each side of the spine, ending on the pelvic bone and the femur and is responsible for the flexion of the hip joint through the connection of the upper body to the lower body. [39,51]

The use of PMA is a user-friendly method for muscle mass measurement, as many CKD patients already undergo routine abdominal CT or MRI scans for transplant evaluation, polycystic kidney disease monitoring, or surgical planning. Despite the psoas being a smaller muscle group, PMA has demonstrated a strong correlation ($r = 0.72$, $p < 0.0001$) with total skeletal muscle area. [52,53] When the authors applied an elliptoid measurement of psoas muscle cross sectional area, the interrater reliability decreased to ICC of 0.599 (95% CI 0.25-0.85).[50]. The elliptoid measurement is an overestimate of the surface area and the direction outline measurement for the muscle mass is required for better results.[50]

There is literature supporting the use of the cross-sectional area of the psoas muscle as a surrogate measure for sarcopenia (refer to Table 3). Using PMA is a measurement applied for the last three decades, as it is found in various studies to estimate skeletal muscle mass. [40–43] The most common radiographic methods used to measure PMA are magnetic resonance imaging (MRI), computed tomography (CT), and DXA. Upon review of the psoas muscle mass morphology on abdominal imaging, three main morphologies were identified: globular, triangular, and elongated. The quantitative measurement of the psoas muscle represents muscle mass but other possibilities of enlarged area may be due to infiltrative or inflammatory disease. Infiltration may be due to granulomatous or tumor cell invasion, tissue deposition or volume expansion and edema. The elongated forms can develop due to abdominal pressure and position leading to the different shape.[86] Its role in clarifying clinical outcomes in various population groups make PMA a widely accepted surrogate to estimate overall lean body mass. [40,41] In some studies, PMA has shown association with post-operative complications such as morbidities and mortality [44,45], it has also proven to positively correlate with weight and BMI. [44,46]. Given its capability of predicting negative health outcomes and in estimating whole lean body mass, PMA could see use in identifying high risk subsets in patients with sarcopenia who would be able to benefit from preop and postop intervention plans to increase overall muscle function. [44]

7. Outcomes of CKD Related to Sarcopenia

The two main outcomes noted in the literature are infections and mortality related to sarcopenia in CKD. Firstly, mortality risk differs according to the degree each component measured for sarcopenia is used for diagnosis. Low physical performance and low muscle strength are associated with a two-fold higher risk of mortality compared to normal performance and muscle strength among the CKD population. [79]. Similarly, low muscle mass is associated with 1.5-fold increased risk of mortality among the CKD population. Over 40% of CKD patients with low body mass index die of cardiac disease.[54]

The second outcome is related to the infection risk where sarcopenia alone- without CKD- increases the odds of infection by 28%. [71]. One in five deaths is due to infection in the low BMI subject with CKD.[54] Mortality risk from Covid was higher in the lower BMI population by 2-4 fold with BMI below 25 or 15 kg/m2 compared to over or equal to 25kg/m2. [48,72] Zhang et al. also reports 56% increase in odds of resp infections amongst confirmed sarcopenia subjects with CKD. [63]. The effect size for infection risk is lower in Frail definition that includes sarcopenia of 11% among CKD patients but this could be due to dilution affect of population selected. [75] Sarcopenia in CKD was documented with all cause infection risk increased by 49%, which also reported no difference noted with the fat quantity present. [63] Chai et al. similarly showed 62% lower odds of infection free

 doi:10.20944/preprints202604.0701.v1

survival with a lowest quartile of PMA value of 2.66 cm2/m among subjects with early grades of CKD. Also, 2-fold higher risk of hospitalization with the lowest PMA quartile value was demonstrated.[12] The relationship between sarcopenia and adverse clinical outcomes is particularly pronounced regarding infectious complications. CKD patients already face a higher burden of respiratory infections and sepsis compared to the general population. Sarcopenia likely exacerbates this vulnerability, as muscle tissue serves as a vital amino acid reservoir required for immune cell proliferation during acute stress [inferred: *this "metabolic buffer" concept is the standard biological explanation for why low muscle mass predicts poor infection survival*]. Given that bacteremia is the second leading cause of death in advanced CKD and End stage kidney disease (ESKD), clarifying the interaction between muscle loss and immune dysfunction is an urgent priority for reducing mortality in this population. Table 4 summarizes the common operational definitions for sarcopenia along with their specific cutoff values.

Table 4. Summary of operational definitions for sarcopenia: several working groups have worked on standardizing the definition of sarcopenia. As noted by the variety of definitions based on chosen method for muscle mass, strength and performance measurements, the prevalence of sarcopenia varies in the populations, such as CKD. Continued efforts should be taken to standardize the definitions that have been proven to have health outcome associated findings.

Working Group	Muscle Mass Measurement and cut offs	Muscle Strength Measurement and cut offs	Muscle Performance Measurement and cut offs	Publication
EWGSOP2	Appendicular Skeletal Muscle Mass (ASMM) <7 kg/m^2 (male) < 6 kg/m^2 (female)	Hand Grip <27 kg (m) <16 kg (w)	Gait Speed ≤ 0.8 m/s	28
EWGSOP	Appendicular Skeletal muscle mass (kg) <7.26 kg/m^2 (male) <5.45 kg/m^2(female)	Hand Grip <30 kg (m) <20 kg (w)	Gait Speed ≤ 0.8 m/s	28,29
AWGS	Age 50-65 Dexa (ASMM) <7.2 kg/m^2 (male) <5.5 kg/m^2 (female) Bioimpedence <7.6 kg/m^2 (male) <5.7kg/m^2 (female) Age >65 Dexa (ASMM) <7.0 kg/m^2 (male) <5.4 kg/m^2 (female) Bioimpedence <7.0 kg/m^2 (male) <5.7 kg/m^2 (female)	Age 50-65 Hand Grip <34 kg (m) <20 kg (w) Age >65 <38 kg (m) <18 kg (w)	Age 50-65 Gait Speed ≤ 1.2 m/s Age >65 ≤ 1.0 m/s	25
(F)NIH	Appendicular lean mass or Appendicular Skeletal Muscle Mass <19.75 kg (male) <15.02 kg (female)	Hand grip <26 kg (male) <16 kg (female)	Gait speed ≤ 0.8 m/s	23

 doi:10.20944/preprints202604.0701.v1

SCWD	Lean appendicular mass /(h^2) (Lean appendicular mass/h^2) of 2SD or more below mean of healthy people between 20 and 30 year old people of the same ethnic group	Hand grip <30 kg (male) <20 kg (female)	Gait speed < 1.0 m/s or who walks less than 400m during 6m walk	55
IWGS	Body Composition (BIA) Appendicular mass/h^2 ≤ 7.23kg/m^2 (male) and ≤5.67 kg/m^2 (female)	Hand grip <30 kg (male) <20 kg (female)	Gait Speed <1.0 m/s	26
ESPEN(SIG)	Muscle Mass Muscle mass 2SD (or more) below mean measured in young adults of same sex and ethnic background Reference population: Rosetta Study		Gait Speed < 0.8 m/s in 4m walk or TUG >20 seconds	30

8. Common Medical Comorbidities and Risk Factors for Sarcopenia Increase Effects of CKD

There are several important comorbidities that contribute to the CKD related outcome risk with sarcopenia, specifically type 2 diabetes mellitus, chronic lung disease, cirrhosis, cardiac and cancer. These conditions are intertwined due to metabolic syndrome resulting in end organ damage, which contribute to sarcopenia development.

9. Type 2 Diabetes

Type-2 Diabetes Mellitus (T2DM) is a common comorbidity which is associated with CKD about 33%. [87] Sarcopenia is known to affect approximately 15% of the diabetic population, while pre-sarcopenia affects approximately 14% of the diabetic population compared to 11% and 8% among healthy controls, respectively. [37,56]. Also, diabetics are approximately at a 1.5 fold increased risk for developing sarcopenia than their non-diabetic counterparts as noted by the pooled OR = 1.518, 95% CI = 1.110 to 2.076, Z-value = 2.611, $p = 0.009$. [56]

10. Chronic Lung Disease and Obstructive Sleep Apnea

Patients with CKD often present with concurrent lung disease, notably chronic obstructive pulmonary disease (COPD) reported in up to 11% of the population and restrictive lung disease in up to 36%. [89] Sarcopenia, however, is also associated with COPD independent of CKD. In studies attempting to estimate the prevalence of sarcopenia in COPD patients, prevalences ranged from 24 to 39.6% . [57,58] Similarly to CKD populations, COPD populations with sarcopenia show a significant impact on morbidity and mortality. Patients with COPD are, once adjusted for age, sex, BMI and smoking history, 1.5 times more likely to have sarcopenia compared to individuals with normal lung capacity. Those with COPD are 3 times more likely to present with sarcopenic obesity than those without COPD, probably due to the use of steroids as part of their therapeutic regime. [59]

Obstructive sleep apnea (OSA) has also been associated with an elevated risk of sarcopenia [68] This is primarily due to a combination of sedentary lifestyle and elevated body mass index. Other comorbidities associated with OSA are depression and osteoporosis, which can further potentiate sarcopenia obesity clinical spectrum.

 doi:10.20944/preprints202604.0701.v1

11. Cirrhosis

About 30% in the general population have non alcoholic cirrhosis and in CKD the prevalence is higher. [90] Starvation, lipolysis with decreased insulin metabolism contribute to the inflammatory state and sarcopenia development in cirrhosis. Other findings proposed that gluconeogenesis and fatty acid oxidation can lead to lower respiratory quotients (RQ) in cirrhotic patients, which can further contribute to the development of sarcopenia. [60] They found that cirrhotic patients have significantly lower RQ compared to healthy controls, which can be result of hypoglycemia and metabolic decompensation. Further along that line, psoas muscle area (PMA) has been shown to correlate highly with RQ. [61] Sarcopenia has a 2-3 fold increased risk in decompensated cirrhosis. [62]. The clinical association remains significant even after adjustment for age, sex, ethnicity, and metabolic risk factors. [62]

12. Cancer

A prospective cohort study reported that, for every 10-mL/min/1.73 m^2 decrease in estimated glomerular filtration rate (eGFR), the risk of cancer increases by 29%. [91] Sarcopenia is associated with increased hospitalization and mortality in cancer cases due to decreased muscle performance and functionality. Patients at risk of developing sarcopenia have lower performance scores with frequent hospitalization and decreased mobility. Fatigue, commonly associated with sarcopenia [76] can also be debilitating for cancer patients, who are already susceptible to fatigue due to their cancer status.

In patients with lung cancer, progression-free survival is lower in sarcopenic patients, with less knowledge of the predictive value of sarcopenia itself on progression free survival, due to the multiple categories of cancer staging and degree of sarcopenia as a study would require a large sample size to detect the effect size in the relationship of progression free survival and degree of sarcopenia. [77]. In breast cancer, sarcopenia can affect approximately 16% of patients, of which 38% are obese and sarcopenic [64]. Colorectal cancer is also commonly linked to sarcopenia, shown in about 39% of colorectal cancer subjects. Within the cancer population, sarcopenia can be associated with a higher rate of infection, length of hospitalization and duration of rehabilitation. [78]. Sarcopenia is also associated with increased risk of overall mortality [65].

13. Cardiovascular Disease

There is a bidirectional relationship of cardiac disease in CKD. In CKD, 21-22% of the population present with cardiac issues upon diagnosis. [88] Over 40% of CKD patients with sarcopenia die of cardiac disease. In severe congestive heart failure, sarcopenia is reported as an important cause of exercise intolerance and ventilatory insufficiency [66]. Sarcopenia-related issues not only lead to increased hospitalizations and decreased survival but also be a culprit in longer hospital stay in this patient population [67]. Exercise intolerance is caused by decreased left ventricular ejection fraction (LVEF) and decreased measured appendicular skeletal muscle (ASM) mass in this population. In cardiac insufficiency, there is documented correlation between ASM mass and limited physical functioning [68].

14. Intevention Strategies in Sarcopenia

Lifestyle management is the most important intervention in CKD population. First and foremost, it empowers the patients to take control of their lives and become an active partner in their treatment. Smoking cessation, weight reduction with sarcopenia and obesity, dietary protein control, limited alcohol intake, regular strengthening and aerobic exercise, and limited salt intake are proven to improve outcomes and are part of current guidelines. Regular physical exercise improves physical fitness, walking capacity, cardiovascular parameters (e.g., blood pressure and heart rate), health-related quality of life, and nutritional parameters [70]. Physical activity is also protective against

 doi:10.20944/preprints202604.0701.v1

depression. [71] In the case of frail patients, usually sedentary, with multiple cardiac risk factors, it is recommended to begin with gradual exercise and under supervision.

Nutrition must be targeted in the frail elderly with CKD because decreasing energy intake is associated with higher stages of CKD. [72] Though in the CKD non dialysis population, nutrition supplementation has not been formally assessed, the general population of frail elderlies have been evaluated with protein supplementation.

Optimal therapy for comorbidities such as sleep apnea management, addiction treatment, antidepressants where necessary, proper primary medical care with vaccinations and cancer screening where appropriate and dietary supervision.

15. Conclusions

Sarcopenia is a very significant associated complication of CKD that can be diagnosed and followed using muscle mass measurements eg. PMA, muscle strength measurements such as hand grip and muscle functionality or performance with gait speed. PMA is a convenient method of muscle mass measurement in CKD over a longitudinal prospective to identify sarcopenia earlier, track the progression over time and intervene with a targeted treatment plan accordingly. It allows for early detection of patients at risk for developing the condition and subsequent proactive intervention. Medical conditions associated with sarcopenia and are coexistent with CKD should be optimally treated to address the sarcopenia, because the sarcopenia can potentially worsen the CKD and other comorbidities by placing the patient at risk for other acute problems such as acute coronary syndrome and infections. The importance of a holistic approach with a primary medical professional, dietician, social work and physiotherapist/kinesiologist provides for a higher probability for sarcopenia mitigation and/or reversal and the prevention of negative health implications such as hospitalizations, infections, cardiac events, and mortality. The economic and psychological burden that accompany sarcopenia and CKD should be further studied to investigate simple and proactive methods of sarcopenia detection. Furthermore, especially in the context of medical comorbidities such as type 2 diabetes, COPD, cirrhosis, cancer and cardiac disease, PMA measurements should be assessed as regular clinical assessments since these conditions could potentiate the risk of sarcopenia development within the CKD population.

Funding: This research was funded by McGill University and Génome Québec Innovation Centre, grant number 172974.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author(s).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Arora P, Vasa P, Brenner D, Iglar K, McFarlane P, Morrison H, Badawi A. Prevalence estimates of chronic kidney disease in Canada: results of a nationally representative survey. CMAJ. 2013 Jun 11;185(9):E417-23.
2. Duarte MP, Almeida LS, Neri SGR, Oliviera JS, Wilkinson TJ, Ribeiro HS, Lima RM. Prevalence of Sarcopenia in patients with chronic kidney disease: global systematic review and meta-analysis. J Cachexia Sarcopenia Muscle. 2024 Apr; 15 (2):501-512
3. Moreno-Gonzalez, R., Corbella, X., Mattace-Raso, F. et al. Prevalence of sarcopenia in community-dwelling older adults using the updated EWGSOP2 definition according to kidney function and albuminuria. *BMC Geriatr* **20** (Suppl 1), 327 (2020).

 doi:10.20944/preprints202604.0701.v1

4. Jeong, H. Y., Ahn, W., Kim, J. C., Choi, Y. B., Kim, J., Jun, H. H., Lee, S., Yang, D. H., Oh, J., Bae, J., & Lee, S. Y. (2019). Sarcopenia is an independent predictor of hospitaliza on in chronic kidney disease outpa ents. Cold Spring Harbor Laboratory
5. Harada K, Suzuki S, Ishii H, Aoki T, Hirayama K, Shibata Y, Negishi Y, Sumi T, Kawashima K, Kunimura A, Shimbo Y, Tatami Y, Kamamiya T, Yamamoto D, Morimoto R, Yasuda Y and Murohara T, (2017) Impact of Skeletal Muscle Mass on Long-term Adverse Cardiovascular Outcomes in Patients with Chronic Kidney Disease, The American Journal of Cardiology, 119(8): 1275-1280
6. Souza VA, Oliviera D, Barbosa SR, Correa J, Colugnati FAB, Mansur HN, Fernandes NMDS, Bastos MG. Sarcopenia in patients with Chronic kidney disease not yet on dialysis: Analysis of the prevalence and associated factors. PLoS One. 2017 Apr 27: 12(4): e0176230.
7. Kim, H., Park, I., Lee, H. S., & Lee, O. (2016). The reliability and validity of gait speed with different walking pace and distances against general health, physical function, and chronic disease in aged adults. *Journal of Exercise Nutrition & Biochemistry*, *20*(3), 46–50.
8. Roshanravan, Baback*; Robinson-Cohen, Cassianne†; Patel, Kushang V.‡; Ayers, Ernest*; Littman, Alyson J.†,§; de Boer, Ian H.*; Ikizler, T. Alp‖; Himmelfarb, Jonathan*; Katzel, Leslie I.¶; Kestenbaum, Bryan*; Seliger, Stephen**. Association between Physical Performance and All-Cause Mortality in CKD. Journal of the American Society of Nephrology 24(5):p 822-830, May 2013.
9. Foley, R. N., Wang, C., Ishani, A., Collins, A. J., & Murray, A. M. (2007). Kidney function and sarcopenia in the United States general population: NHANES III. *American journal of nephrology*, *27*(3), 279-286.
10. Kato, A. (2020). Epidemiology of Sarcopenia and Frailty in CKD. In *Recent Advances of Sarcopenia and Frailty in CKD* (pp. 1-14). Singapore: Springer Singapore.
11. Yang, D., Iqbal, S., Rafatzand, K., & Scheede-Bergdahl, C. (2022). Psoas muscle measurement as a marker of sarcopenia predicts risk of Grade 4 or 5 baseline chronic kidney disease and its progression. *JCSM Rapid Communications*, *5*(2), 182-193.
12. Chai, S. A. (2023). Psoas Muscle Area as a Measure for Sarcopenia and a Predictor of Poor Health Outcomes in Chronic Kidney Disease. McGill University (Canada).
13. Levin, A., Stevens, P. E., Bilous, R. W., Coresh, J., De Francisco, A. L., De Jong, P. E., ... & Winearls, C. G. (2013). Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2012 clinical practice guideline for the evaluation and management of chronic kidney disease. *Kidney international supplements*, *3*(1), 1-150.
14. Tonelli, M., Muntner, P., Lloyd, A., Manns, B. J., James, M. T., Klarenbach, S., ... & Alberta Kidney Disease Network. (2011). Using proteinuria and estimated glomerular filtration rate to classify risk in patients with chronic kidney disease: a cohort study. *Annals of internal medicine*, *154*(1), 12-21.
15. Moorthi, R. N., & Avin, K. G. (2017). Clinical relevance of sarcopenia in chronic kidney disease. *Current opinion in nephrology and hypertension*, *26*(3), 219-228.
16. Bertschi, D., Kiss, C. M., Beerli, N., & Kressig, R. W. (2020). Sarcopenia in hospitalized geriatric patients: insights into prevalence and associated parameters using new EWGSOP2 guidelines. *European Journal of Clinical Nutrition*, *75*(4), 653–660.
17. Volpi, E., Nazemi, R., & Fujita, S. (2004). Muscle <ssue changes with aging. *Current Opinion in Clinical Nutrition and Metabolic Care*, *7*(4), 405–410.
18. Doherty, T. J. (2003). Invited review: aging and sarcopenia. *Journal of applied physiology*, *95*(4), 1717-1727.
19. Beyer, I., Mets, T., & Bautmans, I. (2012). Chronic low-grade inflammation and age-related sarcopenia. *Current Opinion in Clinical Nutrition & Metabolic Care*, *15*(1), 12-22.
20. Marzetti, E., Calvani, R., Bernabei, R., & Leeuwenburgh, C. (2012). Apoptosis in skeletal myocytes: a potential target for interventions against sarcopenia and physical frailty–a mini-review. *Gerontology*, *58*(2), 99-106.
21. Yang, M., Liu, Y., Zuo, Y., & Tang, H. (2019). Sarcopenia for predicting falls and hospitalization in community-dwelling older adults: EWGSOP versus EWGSOP2. *Scien:fic Reports*, *9*(1).
22. Schaap, L. A., Van Schoor, N. M., Lips, P., & Visser, M. (2018). Associations of sarcopenia definitions, and their components, with the incidence of recurrent falling and fractures: the longitudinal aging study Amsterdam. *The Journals of Gerontology: Series A*, *73*(9), 1199-1204.

 doi:10.20944/preprints202604.0701.v1

23. Studenski, S. A., Peters, K. W., Alley, D. E., Cawthon, P. M., McLean, R. R., Harris, T. B., ... & Vassileva, M. T. (2014). The FNIH sarcopenia project: rationale, study description, conference recommendations, and final estimates. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences*, *69*(5), 547-558.
24. Cederholm, T., & Morley, J. E. (2015). Sarcopenia: the new definitions. *Current Opinion in Clinical Nutrition & Metabolic Care*, *18*(1), 1-4.
25. Liang-Kung Chen, Jean Woo, Prasert Assantachai, Tung-Wai Auyeung, Ming-Yueh Chou, Katsuya Iijima, Hak Chul Jang, Lin Kang, Miji Kim, Sunyoung Kim, Taro Kojima, Masafumi Kuzuya, Jenny S.W. Lee, Sang Yoon Lee, Wei-Ju Lee, Yunhwan Lee, Chih-Kuang Liang, Jae-Young Lim, Wee Shiong Lim, Li-Ning Peng, Ken Sugimoto, Tomoki Tanaka, Chang Won Won, Minoru Yamada, Teimei Zhang, Masahiro Akishita, Hidenori Arai, Asian Working Group for Sarcopenia: 2019 Consensus Update on Sarcopenia Diagnosis and Treatment, Journal of the American Medical Directors Association, Volume 21, Issue 3, 2020, Pages 300-307
26. Fielding, R. A., Vellas, B., Evans, W. J., Bhasin, S., Morley, J. E., Newman, A. B., ... & Zamboni, M. (2011). Sarcopenia: an undiagnosed condition in older adults. Current consensus definition: prevalence, etiology, and consequences. International working group on sarcopenia. *Journal of the American Medical Directors Association*, *12*(4), 249-256.
27. Pereira RA, Cordeiro AC, Avesani CM, Carrero JJ, Lindholm B, Amparo FC, Amodeo C, Cuppari L, Kamimura MA. Sarcopenia in chronic kidney disease on conservative therapy: prevalence and association with mortality. Nephrol Dial Transplant. 2015 Oct;30(10):1718-25.
28. Reiss, J., Iglseder, B., Alzner, R., Mayr-Pirker, B., Pirich, C., Kässmann, H., ... & Reiter, R. (2019). Consequences of applying the new EWGSOP2 guideline instead of the former EWGSOP guideline for sarcopenia case finding in older patients. *Age and ageing*, *48*(5), 719-724.
29. Wallengren, O., Bosaeus, I., Frändin, K., Lissner, L., Falk Erhag, H., Wetterberg, H., ... & Skoog, I. (2021). Comparison of the 2010 and 2019 diagnostic criteria for sarcopenia by the European Working Group on Sarcopenia in Older People (EWGSOP) in two cohorts of Swedish older adults. *BMC geriatrics*, *21*(1), 600.
30. Muscaritoli, M., Anker, S. D., Argilés, J., Aversa, Z., Bauer, J. M., Biolo, G. I. A. N. N. I., ... & Sieber, C. C. (2010). Consensus definition of sarcopenia, cachexia and pre-cachexia: joint document elaborated by Special Interest Groups (SIG)"cachexia-anorexia in chronic wasting diseases" and "nutrition in geriatrics". *Clinical nutrition*, *29*(2), 154-159.
31. Ishikawa S et al. (2018) Loop diuretics are associated with greater risk of sarcopenia in patients with non-dialysis-dependent chronic kidney disease. PLoS ONE 13(2):e0192990
32. Sabatino A, Cuppari L, Stenvinkel P, Lindholm B, Avesani CM, Sarcopenia in chronic kidney disease: what have we learned so far?, *Journal of Nephrology*, Volume 34, Issue 4, 1 August 2021, Pages 1347–1372,
33. Gungor O, Sena U, Hasbal NB, Anker SD, and Kalatar-Zadeh, K. Effects of hormonal changes on sarcopenia in chronic kidney disease: where are we now and what can we do? Journal of Cachexia, Sarcopenia and Muscle 2021; 12: 1380-1392.
34. M. Yanishi, H. Kinoshita, H. Tsukaguchi, Y. Kimura, Y. Koito, E. Jino, M. Watanabe, M. Sugi, T. Matsuda, Dual Energy X-ray Absorptiometry and Bioimpedance Analysis are Clinically Useful for Measuring Muscle Mass in Kidney Transplant Recipients With Sarcopenia, Transplantation Proceedings, Volume 50, Issue 1, 2018, Pages 150-154
35. Lee, S. Y. (2019). Sarcopenia is an independent predictor of hospitalization in chronic kidney disease outpatients. *Cold Spring Harbor Laboratory*. Published.
36. Buckinx, F., Reginster, J. Y., Dardenne, N., Croisiser, J. L., Kaux, J. F., Beaudart, C., Slomian, J., & Bruyere, O. (2015). Concordance between muscle mass assessed by bioelectrical impedance analysis and by dual energy X-ray absorptiometry: a cross-sectional study. *BMC Musculoskeletal Disorders*, *16*(1).
37. Wang Z, Zeng S, Li Q, Liu L, Zhong X, Cai L. Correlation between grip strength Z-scores and L3-L4 psoas muscle area Z-scores in pediatric intracranial germ cell tumor patients: A prospective cohort study. Clin Nutr ESPEN. 2025 Dec;70:336-344
38. Huet J, Nordez A, Sarcher A, Mathieu M, Cornu C, Boureau AS. Concordance of Freehand 3D Ultrasound Muscle Measurements With Sarcopenia Parameters in a Geriatric Rehabilitation Ward. J Cachexia Sarcopenia Muscle. 2025 Feb;16(1):e13648.

 doi:10.20944/preprints202604.0701.v1

39. Siccardi MA, Tariq MA, Valle C. Anatomy, Bony Pelvis and Lower Limb: Psoas Major. [Updated 2022 Aug 8]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan
40. Morrell, G. R., Ikizler, T. A., Chen, X., Heilbrun, M. E., Wei, G., Boucher, R., & Beddhu, S. (2016). Psoas Muscle Cross-sectional Area as a Measure of Whole-body Lean Muscle Mass in Maintenance Hemodialysis Pa<ents. *Journal of Renal Nutri:on*, *26*(4), 258–264.
41. Celentano, V., Kamil-Mustafa, L., Beable, R., Ball, C., Flashman, K. G., Jennings, Z., O' Leary, D. P., Higginson, A., & Luxton, S. (2020). Preopera<ve assessment of skeletal muscle mass during magne<c resonance enterography in pa<ents with Crohn's disease. *Updates in Surgery*, *73*(4), 1419–1427.
42. Miller, T. J., Sheckter, C. C., Barnes, B. L. A., Li, A. D. Q., & Momeni, A. (2019). Sarcopenia Is a Risk Factor for Infection for Patients Undergoing Abdominoperineal Resection and Flap-based Reconstruction. *Plastic and Reconstructive Surgery. Global Open*, *7*(7), e2343.
43. Krell, R. W., Kaul, D. R., Mar<n, A. R., Englesbe, M. J., Sonnenday, C. J., Cai, S., & Malani, P. N. (2013). Association between sarcopenia and the risk of serious infection among adults undergoing liver transplantation. *Liver Transplantation*, *19*(12), 1396–1402.
44. Drudi, L., Phung, K., Ades, M., Zuckermann, J., Mullie, L., Steinmetz, O., Obrand, D., Afilalo, J. (2016). Psoas Muscle Area Predicts All-Cause Mortality Afer ENdovascular and Open Aortic Aneurysm Repair. *European Journal of Vascular and Endovascular Surgery*, *52*(6), 764-769.
45. Hawkins, R. B., Mehaffey, J. H., Charles, E. J., Kern, J. A., Lim, D. S., Teman, N. R., & Ailawadi, G. (2018). Psoas Muscle Size Predicts Risk-Adjusted Outcomes After Surgical Aortic Valve Replacement. *The Annals of Thoracic Surgery*, *106*(1), 39–45.
46. Jones, K. I., Doleman, B., ScoI, S., Lund, J. N., & Williams, J. P. (2014). Simple psoas crosssectional area measurement is a quick and easy method to assess sarcopenia and predicts major surgical complications. *Colorectal Disease*, *17*(1), O20–O26.
47. Okada, Y., Kiguchi, T., Okada, A., Iizuka, R., Iwami, T., & Ohtsuru, S. (2021). Predic<ve value of sarcopenic findings in the psoas muscle on CT imaging among pa<ents with sepsis. *The American Journal of Emergency Medicine*, *47*, 180–186.
48. Bahat, G., Turkmen, B. O., Aliyev, S., Catikkas, N. M., Bakir, B., & Karan, M. A. (2021). Cut-off values of skeletal muscle index and psoas muscle index at L3 vertebra level by computerized tomography to assess low muscle mass. *Clinical nutrition*, *40*(6), 4360-4365.
49. Nishimura, T., Naito, H., Fujisaki, N., Ishihara, S., Nakao, A., & Nakayama, S. (2020). The psoas muscle index as a predictor of mortality and morbidity of geriatric trauma patients: experience of a major trauma center in Kobe. *Surgery today*, *50*(9), 1016-1023.
50. Indrakusuma, R., Zijlmans, J. L., Jalalzadeh, H., Planken, R. N., Balm, R., & Koelemay, M. J. (2018). Psoas muscle area as a prognostic factor for survival in patients with an asymptomatic infrarenal abdominal aortic aneurysm: a retrospective cohort study. *European Journal of Vascular and Endovascular Surgery*, *55*(1), 83-91.
51. Touban, B. M., Sayegh, M. J., Galina, J., Pavlesen, S., Radwan, T., & Anders, M. (2022). Computed tomography measured psoas cross sectional area is associated with bone mineral density measured by dual energy X-ray absorptiometry. *Journal of Clinical Densitometry*, *25*(4), 592-598.
52. Lindström, I., Khan, N., Vänttinen, T., Peltokangas, M., Sillanpää, N., & Oksala, N. (2019). Psoas muscle area and quality are independent predictors of survival in patients treated for abdominal aortic aneurysms. *Annals of vascular surgery*, *56*, 183-193.
53. Abbass, T., Ho, Y. T. T., Horgan, P. G., Dolan, R. D., & McMillan, D. C. (2020). The relationship between computed tomography derived skeletal muscle index, psoas muscle index and clinical outcomes in patients with operable colorectal cancer. *Clinical nutrition ESPEN*, *39*, 104-113.
54. Yamamoto, T., Nakayama, M., Miyazaki, M., Sato, H., Matsushima, M., Sato, T., & Ito, S. (2020). Impact of lower body mass index on risk of all-cause mortality and infection-related death in Japanese chronic kidney disease patients. *BMC nephrology*, *21*(1), 244.
55. Bauer, J., Morley, J. E., Schols, A. M., Ferrucci, L., Cruz-Jentoft, A. J., Dent, E., ... & Anker, S. D. (2019). Sarcopenia: a time for action. An SCWD position paper. *Journal of cachexia, sarcopenia and muscle*, *10*(5), 956-961.

 doi:10.20944/preprints202604.0701.v1

56. Chung, S. M., Moon, J. S., & Chang, M. C. (2021). Prevalence of Sarcopenia and Its Association With Diabetes: A Meta-Analysis of Community-Dwelling Asian Population. *Frontiers in Medicine*, *8*.
57. Costa, T. M. D. R. L., Costa, F. M., Moreira, C. A., Rabelo, L. M., Boguszewski, C. L., & Borba, V. Z. C. (2015). Sarcopenia in COPD: relationship with COPD severity and prognosis. *Jornal Brasileiro de Pneumologia*, *41*(5), 415–421.
58. LimpawaIana, P., Inthasuwan, P., Putraveephong, S., Boonsawat, W., Theerakulpisut, D., & Sawanyawisuth, K. (2017). Sarcopenia in chronic obstruc<ve pulmonary disease: A study of prevalence and associated factors in the Southeast Asian popula<on. *Chronic Respiratory Disease*, *15*(3), 250–257.
59. Joppa, P., Tkacova, R., Franssen, F. M., Hanson, C., Rennard, S. I., Silverman, E. K., McDonald, M. L. N., Calverley, P. M., Tal-Singer, R., Spruit, M. A., Kenn, K., Wouters, E. F., & RuIen, E. P. (2016). Sarcopenic Obesity, Functional Outcomes, and Systemic Inflammation in Patients With Chronic Obstructive Pulmonary Disease. *Journal of the American Medical Directors Associa:on*, *17*(8), 712–718.
60. Dhaliwal, A., & Armstrong, M. J. (2020). Sarcopenia in cirrhosis: A practical overview. *Clinical Medicine*, *20*(5), 489–492.
61. Wijarnpreecha, K., Kim, D., Raymond, P., Scribani, M., & Ahmed, A. (2019). Associations between sarcopenia and nonalcoholic faIy liver disease and advanced fibrosis in the USA. *European Journal of Gastroenterology & Hepatology*, *31*(9), 1121–1128.
62. Glass, C., Hipskind, P., Tsien, C., Malin, S. K., Kasumov, T., Shah, S. N., Kirwan, J. P., & Dasarathy, S. (2013). Sarcopenia and a physiologically low respiratory quotient in patients with cirrhosis: a prospective controlled study. *Journal of Applied Physiology*, *114*(5), 559–565.
63. Zhang, X., Zhang, W., Wang, C., Tao, W., Dou, Q., & Yang, Y. (2018). Sarcopenia as a predictor of hospitalization among older people: a systematic review and meta-analysis. *BMC Geriatrics*, *18*(1).
64. Zhang, Y., Weng, S., Huang, L., Shen, X., Zhao, F., & Yan, S. (2022). Association of sarcopenia with a higher risk of infection in patients with type 2 diabetes. *Diabetes-Metabolism Research and Reviews*, *38*(1).
65. Villasenor, A., Ballard-Barbash, R., Baumgartner, K., Baumgartner, R., Bernstein, L., McTiernan, A., & Neuhouser, M. L. (2012). Prevalence and prognostic effect of sarcopenia in breast cancer 83 survivors: the HEAL Study. *Journal of Cancer Survivorship*, *6*(4), 398–406.
66. Suzuki, T., Palus, S., & Springer, J. (2018). Skeletal muscle wasting in chronic heart failure. *ESC Heart Failure*. Published.
67. Martone, A. M., Bianchi, L., Abete, P., Bellelli, G., Bo, M., Cherubini, A., Corica, F., di Bari, M., Maggio, M., Manca, G. M., Marzex, E., Rizzo, M. R., Rossi, A., Volpato, S., & Landi, F. (2017). The incidence of sarcopenia among hospitalized older patients: results from the Glisten study. *Journal of Cachexia, Sarcopenia and Muscle*, *8*(6), 907–914.
68. Fulster, S., Tacke, M., Sandek, A., Ebner, N., Tschope, C., Doehner, W., Anker, S. D., & von Haehling, S. (2013). Muscle wasting in patients with chronic heart failure: results from the studies investigating co-morbidities aggravating heart failure (SICA-HF). *European Heart Journal*, *34*(7), 512–519.
69. Tao, X., Niu, R., Lu, W., Zeng, X., Sun, X., & Liu, C. (2024). Obstructive sleep apnea (OSA) is associated with increased risk of early-onset sarcopenia and sarcopenic obesity: results from NHANES 2015-2018. *International journal of obesity*, *48*(6), 891-899.
70. Cochrane Database Syst Rev. 2011 Oct 5;(10):CD003236. doi: 10.1002/14651858.CD003236.pub2. Exercise training for adults with chronic kidney disease. Heiwe S1, Jacobson SH.
71. Prev Med. 2008 May;46(5):397-411. doi: 10.1016/j.ypmed.2008.01.009. Epub 2008 Jan 26. Physical activity and likelihood of depression in adults: a review. Teychenne M1, Ball K, Salmon J.
72. Br J Nutr. 2014 Jun 28;111(12):2184-9. doi: 10.1017/S0007114514000518. Epub 2014 Mar 17. Renal function associates with energy intake in elderly community-dwelling men. Luis D, Huang X, Sjögren P, Risérus U, Ärnlöv J, Lindholm B, Cederholm T, Carrero JJ.
73. Gao, J., Wang, A., Li, X., Li, J., Zhao, H., Zhang, J., Liang, J., Chen, S., & Wu, S. (2020). The Cumulative Exposure to High-Sensitivity C-Reactive Protein Predicts the Risk of Chronic Kidney Diseases. *Kidney & Blood Pressure Research*, *45*(1), 84–94

 doi:10.20944/preprints202604.0701.v1

74. Imoto, W., Ihara, Y., Imai, T., Tamoto, M., Ibuki, T., Yamada, K., ... & Kakeya, H. (2024). Evaluating the association of body mass index with COVID-19 severity and mortality using Japanese administrative claims data. *Journal of Infection and Chemotherapy*, *30*(10), 1054-1060.
75. Chao, C. T., Lee, S. Y., Wang, J., Chien, K. L., & Huang, J. W. (2021). Frailty increases the risk for developing urinary tract infection among 79,887 patients with diabetes mellitus and chronic kidney disease. *BMC Geriatrics*, *21*(1).
76. Barreto, C. S., Borges, T. C., Valentino, N. P., Gomes, T. L. N., Soares, J. D. P., Siqueira, J. M., Pichard, C., Laviano, A., & Pimentel, G. D. (2021). Absence of risk of sarcopenia protects cancer patients from fatigue. *European Journal of Clinical Nutrition*. Published.
77. Go, S., Park, M., Song, H., Kang, M. J., Park, H. C., Jeon, K. N., Kim, S. H., Kim, M. S., Kang, J. C., & Lee, G. (2016). Sarcopenia and inflammation are independent predictors of survival in male patients newly diagnosed with small cell lung cancer. *Supportive Care in Cancer*, *24*(5), 2075–2084.
78. Lieffers, J. R., Bathe, O. F., Fassbender, K., Winget, M., & Baracos, V. E. (2012). Sarcopenia is associated with postoperative infection and delayed recovery from colorectal cancer resection surgery. *British Journal of Cancer*, *107*(6), 931–936.
79. Ribeiro HS, Neri SGR, Oliviera Js, Bennett PN, Viana JL and Lima BM. Association between sarcopenia, and clinical outcomes in chronic kidney disease patients: A systematic review and meta-analysis. J Cachexia Sarcopenia Muscle. 2024 Apr: 15(2): 501-512
80. Dalrymple, L. S., & Go, A. S. (2008). Epidemiology of Acute Infections among Patients with Chronic Kidney Disease: Figure 1. *Clinical Journal of the American Society of Nephrology*, *3*(5), 1487–1493.
81. Zisman, D. A., Shorr, A. F., & Lynch Iii, J. P. (2002). Sarcoidosis involving the musculoskeletal system. In *Seminars in respiratory and critical care medicine* (Vol. 23, No. 06, pp. 555-570). Copyright© 2002 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel.:+ 1 (212) 584-4662.
82. Xu, J., Zhou, X., Wang, Y., Liu, W., Shan, Y., Zhang, D., ... & Yan, C. (2024). Skeletal muscle involvement in systemic amyloidosis is often overlooked. *Neuropathology and Applied Neurobiology*, *50*(4), e12996.
83. Marcus, R. L., Addison, O., Kidde, J. P., Dibble, L. E., & Lastayo, P. C. (2010). Skeletal muscle fat infiltration: impact of age, inactivity, and exercise. *The Journal of nutrition, health and aging*, *14*(5), 362-366.
84. Parasoglou, P., Rao, S., & Slade, J. M. (2017). Declining skeletal muscle function in diabetic peripheral neuropathy. *Clinical Therapeutics*, *39*(6), 1085-1103.
85. Bennett, J. L., Pratt, A. G., Dodds, R., Sayer, A. A., & Isaacs, J. D. (2023). Rheumatoid sarcopenia: loss of skeletal muscle strength and mass in rheumatoid arthritis. *Nature Reviews Rheumatology*, *19*(4), 239-251.
86. Jokar, F.,Hosseini S.H., and Taheri N., (2024). The relationship of the Psoas major muscle morphology characteristics with disability index, and pain in patients with chronic non-specific low back pain, Journal of bodywork and movement therapies, 38: 454-458.
87. León-Figueroa DA, Aguirre-Milachay E, Barboza JJ, Valladares-Garrido MJ. Prevalence of hypertension and diabetes mellitus in Peruvian patients with chronic kidney disease: a systematic review and meta-analysis. BMC Nephrol. 2024 May 10;25(1):160
88. Minutolo R, Grandaliano G, Di Rienzo P, Snijder R, Degli Esposti L, Perrone V, Todorova L. Prevalence, incidence, and treatment of anaemia in patients with non-dialysis-dependent chronic kidney disease: findings from a retrospective real-world study in Italy. J Nephrol. 2023 Mar;36(2):347-357.
89. Mukai H, Ming P, Lindholm B, Heimbürger O, Barany P, Stenvinkel P, Qureshi AR. Lung Dysfunction and Mortality in Patients with Chronic Kidney Disease. Kidney Blood Press Res. 2018;43(2):522-535.
90. Miguel V, Shaw IW, Kramann R. Metabolism at the crossroads of inflammation and fibrosis in chronic kidney disease. Nat Rev Nephrol. 2025 Jan;21(1):39-56
91. Wong G, Hayen A, Chapman JR, Webster AC, Wang JJ, Mitchell P, Craig JC. Association of CKD and cancer risk in older people. J Am Soc Nephrol. 2009 Jun;20(6):1341-50.