Article

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# Risk Factors for Sarcopenia in Thai Patients with Rheumatoid Arthritis

Wanruchada Katchamart[1,*], Suppavich Kieattisaksopon[2], Pongthorn Narongroeknawin[3], Weerasak Muangpaisan[4], Narittaya Varothai[5]

[1]Division of Rheumatology, Department of Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, 10700 Bangkok, Thailand
[2]Department of Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, 10700 Bangkok, Thailand
[3]Division of Rheumatology, Department of Medicine, Phramongkutklao Hospital, Phramongkutklao College of Medicine, 10400 Bangkok, Thailand
[4]Department of Preventive and Social Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, 10700 Bangkok, Thailand
[5]Division of Geriatric, Department of Medicine, Phramongkutklao Hospital, Phramongkutklao College of Medicine, 10400 Bangkok, Thailand
*Correspondence: wanruchada.kat@mahidol.ac.th (Wanruchada Katchamart)
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**Background: Sarcopenia is a common condition that can occur in people with chronic inflammatory diseases, including rheumatoid arthritis (RA). The aim of this study was to determine the prevalence and factors associated with this condition in patients with RA.**

**Methods: This prospective cross-sectional study was conducted on 182 adult patients with RA. They were diagnosed with sarcopenia using the Asian Working Group's 2019 update on sarcopenia diagnosis. The body composition was estimated using a body impedance analyzer. Physical performance and muscle strength were evaluated with six-meter walk test and hand grip dynamometer, respectively. The Disease Activity Score (DAS) 28 and the Health Assessment Questionnaire (HAQ) were used to assess disease activity and functional status, respectively.**

**Results: The majority (87.4%) were female with a mean age (SD) of 59.2 (10.2) years. They had been suffering from RA for a long time (median disease duration [Interquartile range (IQR)] 11 [6–16] years) and had mildly active disease [mean DAS28 (SD) 2.61 (0.83)] with slightly functional disability [median HAQ (IQR) 0.34 (0–0.65)]. Of these, 26.4% had sarcopenia. Advanced age [relative risk (RR) 1.07 (95% confidence interval (CI) 1.02–1.11), $p = 0.002$], low body mass index (BMI) [RR (95% CI) 0.81 (0.72–0.90), $p < 0.001$], high disease activity [RR (95% CI) 1.64 (1.22–2.12), $p = 0.045$], and depression [RR (95% CI) 1.18 (1.01–1.37), $p = 0.04$] were independently associated with sarcopenia.**

**Conclusions: Sarcopenia was found to be common in Thai RA, and its independent risk factors are age, disease activity, BMI, and depression. Well-controlled disease activity may be beneficial for preventing or minimizing sarcopenia and improving patient outcomes.**

**Keywords:** sarcopenia; rheumatoid arthritis; disease activity; quadriceps strength

## Introduction

Sarcopenia is characterized by the loss of muscle mass accompanied by low muscle strength, and/or low physical performance [1]. The diagnosis of sarcopenia comprise the assessment of muscle mass, muscle strength, and physical performance. Muscle mass assessment can be measured using multiple techniques including bioimpedance analysis (BIA), potassium per fat free soft tissue, radiographic intervention [computerized tomography scan (CT-scan), or magnetic resonance imaging (MRI), dual energy X-ray absorptiometry (DXA)]. Muscle strength can be measured in multiple muscle groups including handgrip strength, knee flexion and extension strength, or peak expiratory flow. Physical performance can be assessed by the short physical performance battery, usual gait speed, timed get-up-and-go test, or the stair climb power test. Patients with sarcopenia tend to have an increased risk of falls, fractures, reduced quality of life, immobility, and mortality [2,3]. Formerly, sarcopenia was thought to be an age-related condition related to neurodegenerative processes [4]. Subsequently, sarcopenia has been recognized in diverse chronic conditions and diseases, including chronic obstructive pulmonary disease [5], chronic liver disease [6], chronic kidney disease [7], chronic heart failure [8], malignancy [9], and rheumatic and autoimmune diseases [10].

Rheumatoid arthritis (RA) is typically presented with chronic polyarthritis resulting in joint deformities, limited physical activities, and loss of muscle mass [11]. Furthermore, the loss of muscle mass in RA may be significantly influenced by elevated inflammatory makers and malnutrition [3]. The reported prevalence of sarcopenia in RA has varied from 8.2% to 88.8% [12] and is considerably more prevalent than the reports in the general population at 1.6–

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68% [13,14]. Information on factors related to sarcopenia in RA may be useful to prevent sarcopenia. However, factors associated with sarcopenia in this disease reported by previous studies were inconsistent [12]. Furthermore, it is currently unclear regarding the prevalence of sarcopenia in Thai individuals with RA and which factors may be associated with its development. Therefore, we aimed to evaluate the prevalence and risk factors for sarcopenia in Thai patients with RA. Additionally, because some RA patients have hand deformities that can impede the reliability of handgrip strength testing, we investigated the diagnostic performance of quadriceps strength-based criteria compared to handgrip strength strength-based criteria for diagnosing sarcopenia in RA. Since the Asian Working Group for Sarcopenia (AWGS) 2014 consensus [1], as well as the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) 2019 consensus [15] recommend knee extension or quadriceps strength as a substitute to handgrip strength measurement.

## Methods

### *Study Population*

A prospective cross-sectional study was carried out on individuals diagnosed with RA who were enrolled in one of two RA registries [Siriraj Rheumatoid Arthritis (SiRA) Registry] [16] or the Thai Army Rheumatoid Arthritis Cohort (TARAC) [17] between June 2020 and December 2020. All patients who were aged 18 years or older and diagnosed with RA according to the 1987 American College of Rheumatology (ACR) revised criteria [18] or the 2010 ACR/European League Against Rheumatism (EULAR) criteria [19], were consecutively recruited. Patients were excluded if they couldn't stand, walk, or perform handgrip strength by themselves, had overlap syndrome with other rheumatic or autoimmune disorders and vasculitides, had other risk factors for sarcopenia, e.g., chronic obstructive pulmonary disease [5,20–22], end stage liver disease [6], neuromuscular disease, or had a metallic device implanted that might interfere with the body impedance analyzer interpretation. All participants were required to provided their informed consent prior to enrollment.

### *Data Collection*

Study data was obtained and administered through the use of REDCap (Research Electronic Data Capture), an electronic data capture tool hosted at the Siriraj Center of Excellence in Bioinformatics and Data Management, Faculty of Medicine Siriraj Hospital, Mahidol University [23].

### *Baseline Characteristics*

Demographic and data related to RA disease activity and treatments were collected as follows: sex, age, occupation, education, tobacco use, alcohol use, comorbidities including cerebrovascular disease, diabetes mellitus, dyslipidemia, hypertension, chronic kidney disease, malignancy, coronary heart disease, pulmonary tuberculosis, chronic hepatitis B, chronic hepatitis C, AIDs, osteoporosis, RA disease duration, extra-articular manifestations, number of tender and swollen joint, patient global assessment of disease activity (PGA) (0 to 10 cm on a visual analogue scale [VAS]), physician global assessment of disease activity (PhyGA) (0 to 10 cm on a VAS), erythrocyte sedimentation rate (ESR), serum albumin, serum globulin, rheumatoid factor (RF), anti-citrullinated peptide antibodies (ACPA), and evidence of radiographic erosion of the hand and feet. The Disease Activity Score (DAS) 28 was calculated to described disease activity [24], while functional status were evaluated using the Thai version of the Health Assessment Questionnaire (HAQ) [25] An individual's level of fatigue during their usual daily activities over the preceding week was measured using the FACIT-Fatigue Subscale, which is a 13-item tool that is easy to administer [26]. Depression and anxiety were measured using the Thai version of the Hospital Anxiety and Depression Scale (Thai HADS) [27]. A score equal to or greater than 8 out of 21 for either type of mood disorder was considered as having anxiety or depression. To evaluate health-related quality of life, the Thai version of EuroQoL five-dimensional questionnaire (EQ-5D-5L) was employed [28]. For nutritional status, the mini nutritional assessment (MNA), a validated questionnaire for evaluating the individuals' nutrition status was applied [29]. An MNA score of less than 17 indicates the presence of malnutrition, while a score of 18–24 suggests the patient is at risk of developing malnutrition.

### *Sarcopenia Assessment*

For body composition assessment, the body impedance analyzer (BIA): Inbody® 720 (InBody Co., Ltd., Cerritos, CA, USA) [30] was used. The height-adjusted appendicular muscle index was calculated. Handgrip strength and quadriceps strength were tested. To measure handgrip strength, participants were seated upright with their upper arm positioned close to their body, their elbow flexion at 90 degrees, and their forearm and wrist in neutral position. The dominant hand's grip strength was measured three times using the handgrip dynamometer (CAMRY® digital). To measure quadriceps or knee extension strength a hand-held dynamometer (HHD) (Lafayette Manual Muscle Test System® Model 01163; Lafayette Instrument Company, Lafayette, IN, USA) was utilized. Participants were instructed to sit upright with their lower legs hanging down and raise their legs until parallel to the floor. Next, they were asked to exert maximum effort against the examiner's resistance for five seconds. Quadriceps strength was measured twice on both sides by the same tester. The greatest values obtained for handgrip strength and quadriceps strength were used for the analyses. Finally, a six-meters walk test was utilized to assess physical performance [31].

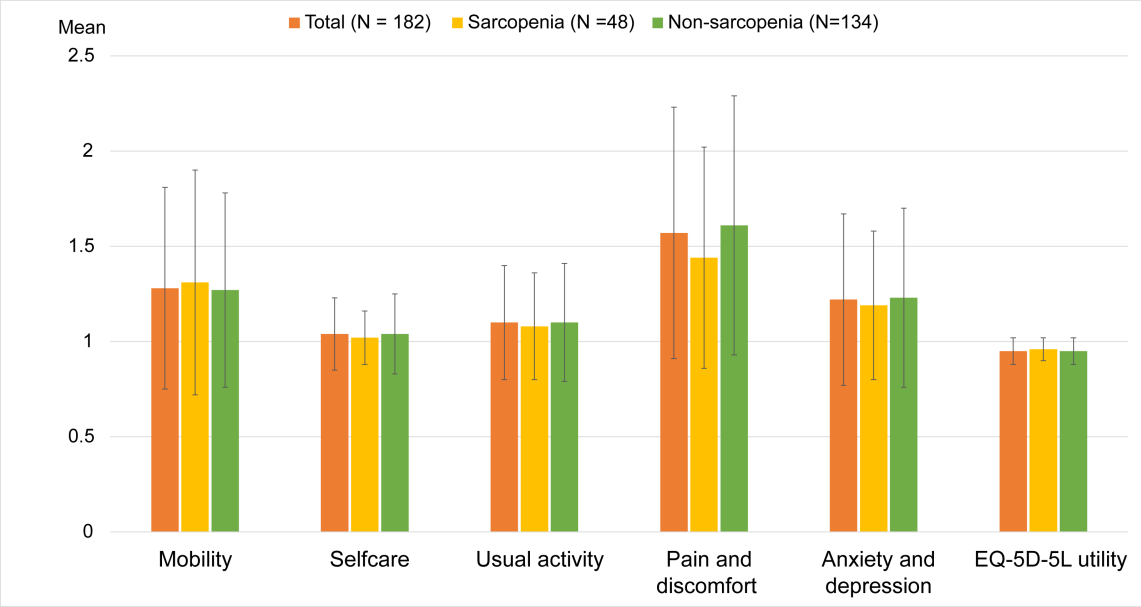


**Fig. 1. Quality of life based on EQ-5D-5L in RA patients with and without sarcopenia.**

According to 2019 Consensus Update on Sarcopenia Diagnosis and Treatment by the Asian Working Group [32], low muscle mass is characterized as appendicular skeletal muscle mass, measured by BIA, of less than 7.0 kg/m$^2$ in men and less than 5.7 kg/m$^2$ in women. Low muscle strength is determined by handgrip strength values of less than 28 kg for men and less than 18 kg for women, and low physical performance is indicated by 6-meter walk values of less than 1.0 meter/second. The cut-off values of quadriceps strength of less than 18 kg in men and less than 16 kg in women indicate low quadricep strength [33]. Sarcopenia was diagnosed if participants had loss of muscle mass, along with low muscle strength, and/or low physical performance. Severe sarcopenia is classified by the simultaneous presence of reduced muscle mass, muscle strength, and physical performance.

### *Statistical Analysis*

For demographic and baseline characteristics, continuous data were described as means and standard deviation (SD, if they followed normal distribution, or as medians and interquartile range (IQR), if they were not normally distributed, and categorical data were reported as percentage. To compare patients with and without sarcopenia, continuous measures were analysed using the independent *t*-test or the Mann-Whitney U-test, whereas proportions were analysed using $\chi^2$ test or Fisher-exact tests, as appropriate. Univariate and multivariate analysis were conducted to identify factors related to sarcopenia. Multiple logistic regression analysis with a backward stepwise elimination approach was performed by including variables that were previously reported to be associated with sarcopenia in other studies. For all primary outcomes, the diagnosis of sarcopenia was based on handgrip strength-based criteria. To investigate the diagnostic performance of quadriceps strength-based criteria for sarcopenia in comparison to handgrip strength-based criteria, sensitivity, specificity, positive predictive value, negative predictive value, and Cohen's kappa for the agreement were calculated. The statistical significance was set at a *p*-value of less than 0.05. All analyses were performed using SPSS Statistics version 20 (SPSS, Inc., Chicago, IL, USA).

## Results

A total of 182 participants with RA were included in this study. The majority (87.4%) were female with a mean age (SD) of 59.2 (10.2) years, and 77% had comorbidities. Dyslipidemia (42.3%), hypertension (29.7%) and diabetes mellitus (11%) were the most common comorbid conditions. They had been suffering from RA for a median disease duration [IQR] of 11 [6–16] years. They had mildly active disease [mean DAS28 (SD) 2.61 (0.83)] and minimal functional disability [median HAQ (IQR) 0.34 (0-0.65)]. RF and ACPA were present in 76.4% and 72.4%, respectively. Extra-articular manifestations were found in thirty patients (16.5%). The mean EQ-5D-5L (SD) and EQ visual analog scale (SD) were 1 (0.1) and 83.5 (14.5), respectively. The mean FACIT-fatigue (SD) scale was 11.9 (5.7). For mood disorders, one patient (0.6%) had depression and three patients (1.7%) had anxiety.

### *Sarcopenia*

Forty-eight (48) of 182 patients (26.4%) were classified as having sarcopenia. Of these, 14 patients (29%) were classified as severe sarcopenia. Patients with sarcopenia were significantly older [mean age (SD) 62.8 (1.4) vs. 57.8

**Table 1. Demographics and baseline characteristics in 182 patients with rheumatoid arthritis.**

| Characteristic | Total (n = 182) | Sarcopenia (n = 48) | Non-sarcopenia (n = 134) | $t$ or $\chi^2$ or Z value | $p$ value |
|---|---|---|---|---|---|
| Age, Mean (SD*), years | 59.2 (10.2) | 62.8 (1.4) | 57.8 (0.9) | –2.98 | 0.003 |
| Female, No (%) | 159 (87.4) | 44 (91.7) | 115 (85.8) | 1.09 | 0.30 |
| BMI, Mean (SD), kg/m$^2$ | 23.4 (4.5) | 21.7 (4.4) | 24.3 (4.1) | 3.96 | <0.001 |
| Smoking, No (%) | 3 (1.6%) | 0 (0%) | 3 (2.2%) | N/A* | 0.57 |
| Alcohol drinking, No (%) | 6 (3.3%) | 0 (0%) | 6 (4.5%) | N/A* | 0.34 |
| Education, mean (SD) years | 4.3 (2.07) | 4.2 (2.07) | 4.3 (2.08) | 0.36 | 0.72 |
| Disease duration, median (IQR), years | 11 (6–16) | 11.5 (7–17) | 11 (6–16) | –0.69 | 0.49 |
| Comorbidities, No. (%) | 140 (76.9%) | 40 (83.3%) | 100 (74.6%) | 1.51 | 0.2 |
| DAS28-ESR (0–9), Mean (SD) | 2.61 (0.83) | 2.82 (0.86) | 2.53 (0.80) | –2.11 | 0.04 |
| HAQ (0–3), Median (IQR) | 0.34 (0–0.5) | 0.34 (0–0.75) | 0.13 (0–0.5) | –1.79 | 0.07 |
| TJC, Median (IQR), joints | 0 (0–0) | 0 (0–0) | 0 (0–0) | –1.29 | 0.19 |
| SJC, Median (IQR), joints | 0 (0–1) | 0 (0–1) | 0 (0–1) | –1.55 | 0.12 |
| PGA, Median (IQR) | 0 (0–1) | 0 (0–1) | 0.5 (0–1) | –0.13 | 0.89 |
| PhyGA, Median (IQR) | 0 (0–1) | 0 (0–1) | 0 (0–1) | –0.03 | 0.98 |
| Rheumatoid factor positivity, No. (%) | 139 (76.4) | 34 (70.8) | 105 (78.4) | 1.11 | 0.29 |
| ACPA positivity, No (%) | 131 (72.4) | 33 (68.8) | 98 (73.7) | 0.43 | 0.51 |
| Hemoglobin, mean (SD), g/dL | 12.4 (1.4) | 12.1 (1.2) | 12.5 (1.5) | 1.37 | 0.17 |
| Albumin, mean (SD), g/dL | 4.3 (0.6) | 4.2 (0.3) | 4.4 (0.7) | 1.13 | 0.26 |
| Globulin, mean (SD), g/dL | 3.4 (0.5) | 3.5 (0.6) | 3.4 (0.5) | –0.69 | 0.5 |
| ESR, median (IQR), mm/hr | 30 (17–48) | 46.5 (21–58.5) | 30 (16–44) | –2.75 | 0.01 |
| Extra articular manifestation No. (%) | 30 (16.5) | 7 (14.6) | 23 (17.2) | 0.17 | 0.68 |

ACPA, anti-citrullinated peptide antibodies; BMI, body mass index; DAS28-ESR, disease activity score 28-ESR; ESR, erythrocyte sedimentation rate; HAQ, health assessment questionnaire; IQR, interquartile range; SD, standard deviation; PGA, patient global assessment of disease; PhyGA, physician assessment of disease activity; SJC, swollen joint count; TJC, tender joint count.
*Fisher exact test.

(0.9), $p = 0.003$] and had lower low body mass index (BMI) than those without sarcopenia [21.0 (4.4) vs. 24.3 (4.1), $p < 0.0001$]. Patients with sarcopenia group exhibited significantly more active disease when compared to those without sarcopenia as evidenced by a higher mean DAS28 2.82 (0.86) vs. 2.53 (0.80), $p = 0.04$ and ESR 46.5 (21–58.5) vs. 30 (16–44), $p = 0.01$. While the former group also tended to exhibit more functional impairment [mean HAQ 0.34 (0–0.75) vs. 0.13 (0–0.5), $p = 0.07$]. There was no significant difference observed between sarcopenic vs. non-sarcopenic groups regarding the percentage of RF ($p = 0.29$) and ACPA positivity ($p = 0.51$), mean hemoglobin level ($p = 0.17$), serum albumin ($p = 0.26$), and serum globulin ($p = 0.5$) (Table 1).

Patients with sarcopenia reported their EQ-5D-5L utility and EQ visual analog scale as 0.96 and 84.2% respectively, which were in not different in patients without sarcopenia (Fig. 1). Sarcopenia patients had significantly lower MNA screening scores [mean (SD) 11.5 (2.1) vs. 12.5 (1.7), $p = 0.002$], status score [mean (SD) 12.3 (2.0) vs. 13.1 (1.5), $p = 0.005$], and total score [mean (SD) 23.9 (3.4) vs. 25.6 (2.4), $p < 0.0001$]. The proportion of sarcopenia patients who were at risk of malnutrition (41.67% vs. 20.15%, $p = 0.003$) and those suffering from malnutrition (6.25% vs. 0%, $p = 0.02$) were both significantly higher when compared to the non-sarcopenic group. Sarcopenic patients had a significantly higher median HADS depression score (IQR) [3 (1–5) vs. 2 (1–4), $p = 0.027$], but proportion of patients with depression and anxiety were not significantly different between groups (**Supplementary Table 1**). No significant differences were observed in the scores of the FACIT fatigue scale between the sarcopenia vs. non-sarcopenia groups [mean FACIT-F score (SD) 12.1 (6.6) in sarcopenia vs. 11.9 (5.4) in without sarcopenia, $p = 0.83$].

Patients diagnosed with sarcopenia exhibited significantly lower core muscle mass ($p = 0.002$), appendicular muscle mass ($p < 0.001$), total muscle mass index ($p = 0.005$), as well as handgrip ($p < 0.001$) and quadriceps strength ($p < 0.001$) when compared to those without the condition. Furthermore, sarcopenic patients required significantly more time in the six meters walk ($p < 0.001$) (Fig. 2, **Supplementary Table 2**).

### *Risk Factors for Sarcopenia*

The univariate analysis revealed that age, BMI, DAS28, and ESR were all significantly related to sarcopenia (Table 1). In multivariate analysis using a backward stepwise approach, only age [odds ratio (OR) (95% confidence interval (CI)) 1.07 (1.02–1.11), $p = 0.002$], disease activity (measured by DAS28) [OR (95% CI) 1.64 (1.22–2.12), $p = 0.045$], and depression [OR (95% CI) 1.18 (1.01–

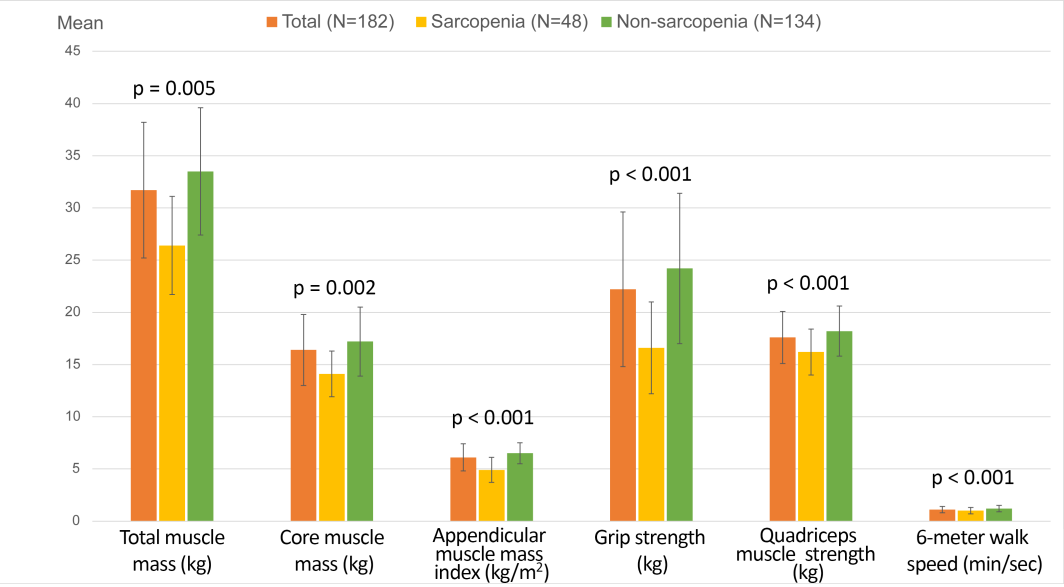


**Fig. 2. Muscle quality and quantity.** kg, kilogram; m, meter; min, minute; sec, second.

1.37), $p = 0.04$] significantly increased the risk, while there was a significantly inverse association observed between BMI and sarcopenia with OR (95% CI) 0.81 (0.72–0.90), $p < 0.001$. The Cox & Snell R Square for prediction was 18.5%.

### *Diagnostic Performance of Quadriceps Strength-Based Criteria*

Thirty-seven patients (20%) were diagnosed with sarcopenia based on quadriceps strength-based criteria. Using handgrip strength-based criteria as the gold standard, quadriceps strength-based criteria demonstrated 66.7% (95% CI: 53.3–80) sensitivity, 96.3% specificity (95% CI: 93–99.5), 88.46% (95% CI: 83.8–93.1) overall accuracy, with 86.5% (95% CI: 75.5–97.5) positive predictive value, and 89.0% (95% CI: 83.9–97.1) negative predictive value. The agreement between quadriceps strength-based criteria and handgrip strength-based criteria for diagnosis of sarcopenia was moderate with Cohen's kappa of 0.68 ($p < 0.001$).

## Discussion

In this prospective cross-sectional study, the prevalence of sarcopenia in RA patients was 31%, which is compatible with previously reported rates (range 8–88%) included in a meta-analysis by Li T-H *et al.* [12]. This variation in reported prevalence reflects the difference in ethnicities, criteria for diagnosis of sarcopenia, diagnostic modalities, disease duration, disease activity, and the functional status of each study population. We used the 2019 criteria for the diagnosis of sarcopenia [32], while other studies used the older criteria. Therefore, comparison of the prevalence of sarcopenia among studies must be done with caution. Despite this limitation, it is clear that sarcopenia is common in RA patients. When compared to a recent study in Thai elderly using the 2019 handgrip strength-based criteria for diagnosis of sarcopenia [33], the sarcopenia in RA is more prevalent than in Thai elderly (26.4% vs. 13.9%). This suggests that sarcopenia should be regarded as another common extra-articular manifestation of RA that may lead to adverse health-related outcomes. Interestingly, rather than having only low appendicular mass due to peripheral joint inflammation, pain, and deformity, RA patients often have low core muscle mass. This finding suggests that in addition to disuse atrophy and local joint inflammation, persistent systemic inflammation, a hallmark of RA may contribute to the development of sarcopenia.

Consistent with other studies, we found that advanced age and low BMI are risk factors for sarcopenia [12,15,32,34–39]. Moreover, our findings indicate that there is a higher likelihood of depression in patients with sarcopenia. Depression may be either the cause or outcome of sarcopenia. Individuals with sarcopenia tend to be more inert than those without sarcopenia, resulting in declining physical and mental activity that can lead to depression. Conversely, reduced physical activity also leads to disuse muscle atrophy and poor muscle performance. As the study design of this study was cross-sectional, it is impossible to determine a causal relationship between sarcopenia and mood disorders. Consistent with earlier studies, we observed a positive correlation between the prevalence of sarcopenia and RA disease activity [12,40–42]. In addition, a meta-analysis by Li, T-H *et al.* [12] reported that high C-reactive protein, an inflammatory marker for active disease, was associated with sarcopenia in RA [34,41,43]. RA patients were shown to have high levels of inflammatory cytokines, including tumor necrotic factor-alpha (TNF-$\alpha$) and interleukin-1-beta

(IL-1$\beta$), leading to hypermetabolism [44]. These patients had lower body cell mass and cachexia despite an otherwise sufficient dietary intake [44]. Furthermore, patients with active disease usually have limited physical activity due to fatigue, joint pain and deformities, leading to low muscle mass due to disused atrophy, low muscle strength, and impaired muscle performance. Therefore, life-long tight control of disease activity should improve the patients' appetite and nutritional status, and enable increased physical activity that should reduce the occurrence of sarcopenia.

We found that malnutrition is an important factor contributing to sarcopenia. A study by Tański W *et al.* [45], demonstrated that higher levels of malnutrition were linked to more restriction in physical activity, leading to impaired functional status and poor muscle performance. Malnutrition in RA may be caused by a lack of appetite, which is related to high inflammatory cytokine production, including TNF-$\alpha$, IL1, IL6, etc. in RA patients with active disease. Furthermore, some Thai patients try to avoid meat intake since they believe that by eliminating processed and red meat, joint pain and inflammation can be reduced. Adequate dietary protein intake and sufficient physical activity are crucial in promoting muscle protein synthesis [46], therefore careful nutritional guidance and exercise should be emphasized to all RA patients.

In addition to previously reported factors related to sarcopenia, lack of estrogen may contribute to sarcopenia in our female participants at perimenopausal age, as estrogen deficiency has been shown to induce skeletal muscle apoptosis, impair muscle regeneration, and contribute to muscle atrophy and weakness [47].

Patients with RA may have severe hand deformities that interfere with the reliability of handgrip muscle strength assessment. Therefore, using quadriceps strength instead of handgrip strength for muscle strength assessment should be more appropriate as demonstrated in a recent study in the elderly by Assantachai P *et al.* [33]. However, the diagnostic performance of the criteria using quadriceps strength assessment in the elderly was slightly better than in our study with an overall accuracy of 99.2%, 100% sensitivity, and 99.1% specificity. While the positive predictive value was 94.6% (95% CI: 85.1–98.2) and the negative predictive value was 100% (95% CI: 98.8–100) [33]. This discrepancy may be caused by the variation of location of arthritis among patients, which may be localized at either the hands or knees, or both. Nevertheless, we measured an acceptable level of agreement between handgrip strength and quadriceps strength-based diagnostic criteria. Additionally, quadriceps muscle strength in sarcopenic groups was significantly lower than those in non-sarcopenic group. Therefore, we conclude that quadriceps and handgrip strength assessment are interchangeable in RA. However, selection of muscle strength assessment modalities in RA should be individualized based on the location of joint involvement.

This study has some limitations. First, we excluded patients with severe hand deformities and those who had undergone arthroplasty because they were unable to complete handgrip/ bioimpedance muscle strength analysis. Patients with more severe disease who tend to have sarcopenia were excluded from this study. Therefore, we may have underestimated the prevalence of sarcopenia in Thai RA population. Second, this study was conducted in tertiary referral centers where a tight control strategy is implemented as routine care, so most patients in our study had low disease activity and minimal functional limitation. Consequently, the prevalence of sarcopenia we report may be lower than those of other RA patients outside this study.

## Conclusions

In conclusion, RA commonly experienced sarcopenia, characterized by low appendicular and core muscle mass. Sarcopenia in RA is associated with advanced age, low BMI, high disease activity, and mood disorder. Therefore, preventing sarcopenia may be possible through a life-long tight control strategy focused on achieving remission, or lower disease activity.

## Availability of Data and Materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## Author Contributions

WK, SK, PN and WM designed the research study. WK, SK, PN, WM and NV performed the research. WK and SK analyzed the data. All authors drafted the work and substantively revised it, approved the submitted version, and contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

## Ethics Approval and Consent to Participate

This study followed the ethical principles set forth in the Declaration of Helsinki and the Guideline for Good Clinical Practice International Conference on Harmonization (ICH) Tripartite Guideline (January 1997). The study protocol was approved by the Siriraj institutional review board (Si184/2020) and the institutional review board of the Royal Thai army medical department (S033q/63). Informed consent was obtained from all participants prior to enrollment.

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## Conflict of Interest

The authors declare no conflict of interest.

## Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.24976/Discov.Med.202335176.44.

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