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THE RELATIONSHIP BETWEEN VITAMIN D INTAKE AND PLASMA C-REACTIVE PROTEIN LEVELS AND APPENDICULAR SKELETAL MUSCLE INDEX IN ADULTS WITH OBESITY

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ABSTRACT
Obesity is commonly associated with chronic low-grade inflammation and alterations in skeletal muscle mass, increasing the risk of sarcopenic obesity. Vitamin D deficiency and elevated C-reactive protein (CRP) levels are frequently observed in individuals with obesity and may contribute to impaired muscle metabolism. This study aimed to examine the relationship between vitamin D intake, plasma C-reactive protein (CRP) levels, and the Appendicular Skeletal Muscle Index (ASMI) among obese adults at Universitas Indonesia Hospital (RSUI). An analytical cross-sectional design was employed involving 70 obese adults aged 18–59 years. Vitamin D intake was assessed using a semi-quantitative food frequency questionnaire, plasma CRP levels were measured using enzyme-linked immunosorbent assay (ELISA), and ASMI was determined using bioelectrical impedance analysis. Data were analyzed using univariate, bivariate, and multivariate statistical methods. The results showed that most participants had inadequate vitamin D intake and elevated plasma CRP levels, indicating the presence of systemic inflammation. No significant association was found between vitamin D intake and CRP levels or between vitamin D intake and ASMI. However, plasma CRP levels demonstrated a weak but statistically significant association with ASMI. These findings suggest that inflammation plays a more prominent role than vitamin D intake in influencing skeletal muscle mass among obese adults, highlighting the multifactorial nature of sarcopenic obesity.

INTRODUCTIONS

Sarcopenic obesity is a condition characterized by the loss of skeletal muscle mass and function accompanied by excess adipose tissue. A meta-analysis published in 2021 reported that the global prevalence of sarcopenic obesity was 11%. Sarcopenic obesity is associated with an increased risk of fractures, cardiovascular disease, diabetes mellitus, and cancer (Gao et al., 2021). Obesity is a chronic multifactorial condition resulting from an imbalance between energy intake and expenditure, leading to excessive fat accumulation and being associated with various diseases and health disorders (Karampela et al., 2021). In 2022, approximately 890 million adults (16%) worldwide were living with obesity (WHO, 2024). Data from the 2018 Indonesian Basic Health Research (Riskesdas) showed an increasing prevalence of obesity among adults from 2007 to 2018. In 2018, the prevalence of adult obesity in Indonesia reached 21.8%. West Java Province ranked 14th highest in adult obesity prevalence in Indonesia in 2018 (approximately 22%) (Badan Penelitian dan Pengembangan Kesehatan Kementerian RI, 2018). Meanwhile, according to the West Java Health Profile Report, the prevalence of obesity among individuals aged over 15 years in Depok City reached 43.18% in 2018. Depok is home to hospitals that provide integrated services for patients with obesity, one of which is Universitas Indonesia Hospital (RSUI) (Badan Penelitian dan Pengembangan Kesehatan Kemenkes RI, 2019).

Individuals with obesity commonly experience micronutrient deficiencies, including vitamin D deficiency (Karampela et al., 2021). In people with obesity, a greater proportion of vitamin D is sequestered in adipose tissue, resulting in reduced bioavailability for biological functions (Mahan & Raymond, 2017). Vitamin D deficiency may increase the risk of inflammation and impair the resolution of inflammatory processes, thereby contributing to chronic inflammation. The main sources of vitamin D are sunlight exposure and dietary intake, such as salmon, tuna, eggs, and vitamin D–fortified foods; thus, inadequate dietary intake of vitamin D–rich foods can lead to vitamin D deficiency. A study conducted in 2021 among individuals aged 17–35 years found that 68.5% of 127 respondents had inadequate vitamin D intake, indicating that insufficient intake is one of the contributing factors to vitamin D deficiency (Nugraha et al., 2017; Prasetyo et al., 2022).

On the other hand, weight gain is associated with increased quantity and altered distribution of adipose tissue, which may disrupt adipokine secretion. Hypertrophic adipocytes secrete pro-inflammatory factors due to reduced production of insulin-sensitive adipokines (Zakharova et al., 2019). Persistent elevation of pro-inflammatory cytokines, one of which is reflected by increased C-reactive protein (CRP) levels, is thought to interfere with muscle protein synthesis through increased insulin resistance and anabolic resistance, as well as to promote muscle protein breakdown (protein degradation) (Axelrod et al., 2023; Badan Penelitian dan Pengembangan Kesehatan Kemenkes RI, 2019; Clark et al., 2016; Han et al., 2019; IHME, 2019; Nari et al., 2020; Tuttle et al., 2020). Furthermore, chronic inflammatory conditions increase the energy demand required to counteract inflammation, part of which is derived from protein catabolism. This process also contributes to the reduction of muscle mass and, if sustained, may increase the risk of sarcopenic obesity (Argilés et al., 2016; Axelrod et al., 2023; Han et al., 2019; Ji et al., 2022; Wei et al., 2023).

One method for assessing muscle mass is the measurement of the Appendicular Skeletal Muscle Index (ASMI), which is calculated as the sum of skeletal muscle mass of the four extremities divided by height squared (Tuttle et al., 2020). However, the relationship between vitamin D intake, CRP levels, and Appendicular Skeletal Muscle Index in Indonesia has not yet been well established. Therefore, further research is needed to examine the associations among these three variables.

This study aims to examine the relationship between vitamin D intake, plasma C-reactive protein (CRP) levels, and the Appendicular Skeletal Muscle Index (ASMI) among adults with obesity at Universitas Indonesia Hospital (RSUI). Specifically, the study seeks to describe the levels of vitamin D intake, plasma CRP, and ASMI in obese adult patients, and to analyze the associations between vitamin D intake and plasma CRP levels, vitamin D intake and ASMI, plasma CRP levels and ASMI, as well as the combined relationship of vitamin D intake and plasma CRP levels with ASMI in this population.

Literature Review

Obesity

Obesity is defined as an excessive or abnormal accumulation of adipose tissue that impairs health and is strongly associated with an increased risk of diabetes mellitus, cardiovascular disease, hypertension, and dyslipidemia (Mousa et al., 2020). In Asian populations, including Indonesia, adult nutritional status is commonly classified using the WHO Asia–Pacific body mass index (BMI) criteria, which provide lower BMI cut-off points to reflect higher metabolic risk at lower BMI values compared to Western populations (Inoue et al., 2000).

Obesity is a multifactorial condition resulting from chronic energy imbalance between caloric intake and energy expenditure. Its development is influenced by genetic predisposition, socioeconomic conditions, sedentary lifestyle, sleep disturbances, endocrine disorders, medication use, dietary patterns rich in refined carbohydrates and sugars, and reduced basal metabolic rate (Mousa et al., 2020). Genetic factors affect adipocyte number and size, fat distribution, resting metabolic rate, and hormonal regulation of appetite and energy expenditure. Mutations or altered expression of genes such as the leptin (Ob) gene, leptin receptors, adiponectin, and β3-adrenergic receptors have been implicated in the pathogenesis of obesity, particularly under high-fat dietary conditions (Mahan & Raymond, 2017).

Adipose tissue also functions as an active endocrine and immune organ. In obesity, adipocyte hypertrophy and adipose tissue expansion lead to hypoxia, oxidative stress, and dysregulated secretion of adipokines, resulting in a chronic low-grade inflammatory state. Adipocytes and infiltrating immune cells secrete pro-inflammatory cytokines, including interleukin (IL)-6, tumor necrosis factor-α (TNF-α), and IL-1β, which contribute to insulin resistance, dyslipidemia, and muscle protein loss (Mahan & Raymond, 2017). These inflammatory processes establish a strong link between obesity and chronic inflammatory diseases such as type 2 diabetes mellitus, cardiovascular disease, and certain malignancies.

Additionally, gut microbiota composition plays a critical role in obesity. An increased ratio of Firmicutes to Bacteroidetes has been associated with enhanced energy harvest and weight gain, whereas higher proportions of Bacteroidetes are linked to improved weight regulation (Mahan & Raymond, 2017). Diet-induced alterations in gut microbiota therefore contribute to metabolic dysregulation in obesity.

Vitamin D

Vitamin D is a fat-soluble vitamin stored predominantly in adipose tissue. In individuals with obesity, a larger proportion of vitamin D is sequestered in fat depots, reducing its bioavailability for physiological functions and increasing the risk of vitamin D insufficiency (Mahan & Raymond, 2017).

Vitamin D synthesis begins in the skin, where 7-dehydrocholesterol is converted into previtamin D_3 following exposure to ultraviolet B (UVB) radiation (290–320 nm). Previtamin D_3 is subsequently isomerized into cholecalciferol (vitamin D_3), which is transported to the liver bound to vitamin D–binding protein (DBP) and hydroxylated to 25-hydroxyvitamin D [25(OH)D]. Further hydroxylation in the kidneys produces the biologically active form, 1,25-dihydroxyvitamin D [1,25$(OH)_2$D] (Dominguez et al., 2021). Factors such as age, skin pigmentation, sunscreen use, clothing, geographic location, and sun exposure duration significantly influence cutaneous vitamin D synthesis (Dominguez et al., 2021).

Dietary sources of vitamin D are relatively limited and include fatty fish, fish liver oils, egg yolks, mushrooms exposed to UV light, and fortified foods such as milk and plant-based beverages (Mahan & Raymond, 2017; Mousa et al., 2020; Prasetyo et al., 2022). According to the Indonesian Recommended Dietary Allowance (RDA), the daily requirement of vitamin D for adults aged 19–64 years is 15 µg (600 IU), increasing to 20 µg (800 IU) for individuals aged 65 years and older (Kemenkes, 2019).

Assessment of vitamin D intake presents methodological challenges due to day-to-day variability in food consumption. While 24-hour dietary recall is considered a gold standard for dietary assessment, it may inadequately capture habitual vitamin D intake. Semi-quantitative food frequency questionnaires (SQFFQ) are therefore considered more suitable for estimating long-term micronutrient intake, including vitamin D (Bijani et al., 2018; Clark et al., 2016; Hribar et al., 2022).

C-Reactive Protein (CRP)

C-reactive protein (CRP) is an acute-phase pentameric protein synthesized by the liver in response to inflammation, primarily under the stimulation of IL-6. In healthy adults, CRP levels are typically below 0.3 mg/dL, while higher concentrations reflect increasing degrees of inflammatory activity (Singh et al., 2025). Mild elevations are commonly observed in obesity, pregnancy, smoking, sedentary behavior, and metabolic disorders, whereas moderate to severe elevations indicate systemic inflammation, infection, autoimmune disease, or tissue injury (Singh et al., 2025).

CRP exhibits both pro-inflammatory and anti-inflammatory properties, participating in pathogen recognition, complement activation, and clearance of apoptotic cells. However, persistently elevated CRP levels indicate chronic inflammation and are associated with adverse metabolic and cardiovascular outcomes (Singh et al., 2025). In obesity, expanded adipose tissue serves as a major source of IL-6, thereby stimulating hepatic CRP synthesis. Anthropometric indicators such as BMI and waist circumference show positive correlations with circulating CRP levels, particularly in individuals with excess visceral fat (Radi et al., 2017).

Appendicular Skeletal Muscle Index (ASMI)

Appendicular Skeletal Muscle Index (ASMI) is a standardized measure of muscle mass used in the diagnosis of sarcopenia. According to the Asian Working Group for Sarcopenia (AWGS), low muscle mass is defined as an ASMI <7.0 kg/m² in men and <5.4 kg/m² in women (Lee et al., 2023). Obesity is increasingly recognized as a condition characterized not only by excess adiposity but also by impaired skeletal muscle quantity and quality, a phenomenon known as sarcopenic obesity (McCuller et al., 2023).

Direct imaging methods such as computed tomography (CT) and magnetic resonance imaging (MRI) provide accurate muscle mass measurements but are limited by cost and radiation exposure. Dual-energy X-ray absorptiometry (DXA) offers high accuracy with lower radiation but limited accessibility. Bioelectrical impedance analysis (BIA) is therefore widely used in clinical and research settings due to its safety, affordability, and feasibility. ASMI is calculated by dividing appendicular skeletal muscle mass by height squared (Hribar et al., 2022; Jeon et al., 2020; McCuller et al., 2023; Sánchez-Iglesias et al., 2012).

Vitamin D, CRP, and ASMI in Obesity

Obesity-related adipose tissue expansion promotes chronic inflammation through adipokine imbalance and immune cell infiltration, particularly macrophage polarization toward the pro-inflammatory M1 phenotype (Zakharova et al., 2019). This inflammatory milieu contributes to insulin resistance and elevated CRP levels. Vitamin D plays a modulatory role in these processes by regulating adipokine expression, suppressing pro-inflammatory cytokines, and inhibiting nuclear factor kappa B (NF-κB) signaling pathways (Montenegro et al., 2019; Zakharova et al., 2019).

Vitamin D insufficiency is commonly observed in obesity due to adipose tissue sequestration, reduced sun exposure, and impaired hepatic hydroxylation. Adequate vitamin D status has been associated with lower CRP concentrations and reduced systemic inflammation (Zakharova et al., 2019). Furthermore, vitamin D influences skeletal muscle metabolism through activation of the vitamin D receptor (VDR), which regulates myogenesis, mitochondrial function, calcium homeostasis, and insulin signaling pathways (Dzik & Kaczor, 2019; Montenegro et al., 2019).

Low vitamin D levels are associated with muscle atrophy, reduced ASMI, and increased risk of sarcopenia. Experimental and clinical studies demonstrate that $1,25(OH)_2D$ enhances muscle protein synthesis through Akt/mTOR signaling, improves mitochondrial oxidative capacity, and mitigates oxidative stress, thereby preserving muscle mass and function (Dzik & Kaczor, 2019; Montenegro et al., 2019). Chronic inflammation and oxidative stress in obesity further exacerbate muscle catabolism, linking vitamin D deficiency, elevated CRP, and reduced ASMI in obese adults.

RESEARCH METHODS

This study employed an analytical cross-sectional design to examine the association between vitamin D intake, plasma C-reactive protein (CRP) levels, and the Appendicular Skeletal Muscle Index (ASMI) among adults with obesity. The study was conducted at Universitas Indonesia Hospital (RSUI), Depok, Indonesia, between May and June 2024. The target population comprised obese adults in Depok, with eligible participants recruited consecutively from patients attending RSUI who met the inclusion criteria (aged 18–59 years, BMI ≥25 kg/m², able to communicate in Indonesian, and provided informed consent). Individuals with chronic or infectious diseases, pregnancy, physical disabilities affecting standing posture, implanted electronic devices, active prostheses, or poor cooperation were excluded.

Vitamin D intake was assessed using a semi-quantitative food frequency questionnaire (SQ-FFQ) and analyzed with NutriSurvey. Plasma CRP levels were measured using the enzyme-linked immunosorbent assay (ELISA) method from venous blood samples. ASMI was determined using bioelectrical impedance analysis (BIA)

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(SECA 515) and calculated as appendicular skeletal muscle mass divided by height squared. Sociodemographic variables and sunlight exposure were collected through structured interviews.

A minimum sample size of 70 participants was calculated based on a correlation study formula, including a 10% attrition allowance. Data were analyzed using univariate, bivariate, and multivariate statistical analyses. Normality was assessed using the Kolmogorov–Smirnov test. Pearson or Spearman correlation tests were applied as appropriate, followed by multiple regression analyses to control for potential confounders. Data were presented in textual and tabular forms.

RESULTS AND DISCUSSION

General Characteristics of the Respondents

This study included 70 adults with obesity who met the inclusion and exclusion criteria at Universitas Indonesia Hospital. The respondents were predominantly in the productive age group, with the largest proportion aged 30–39 years (34.3%), followed by those aged 24–29 years (28.6%). Females constituted the majority of participants (68.6%), while males accounted for 31.4%. Almost all respondents had completed higher education (98.6%), indicating a highly educated study population. In terms of socioeconomic status, most participants (91.4%) had a monthly household income equal to or above the regional minimum wage threshold, reflecting a predominantly middle-to-high economic background. These demographic and socioeconomic characteristics provide an important contextual basis for interpreting the relationships between vitamin D intake, plasma C-reactive protein (CRP) levels, and the Appendicular Skeletal Muscle Index (ASMI).

Univariate Analysis

1. Vitamin D Intake

   Vitamin D intake was assessed using a semi-quantitative food frequency questionnaire (SQ-FFQ) and analyzed with NutriSurvey, then compared with the recommended dietary allowance for adults (15 µg/day or 600 IU).

   Table 1. Respondents' Vitamin D Intake

Variable	Mean ± SD (µg/day)	Minimum (µg/day)	Maximum (µg/day)
Vitamin D Intake	54,39 ± 95,91	3	645

   The mean vitamin D intake among respondents was 54.39 ± 95.91 µg/day, with values ranging from 3 to 645 µg/day. This wide range and large standard deviation indicate substantial variability in intake, partly due to a small number of participants with very high vitamin D consumption, likely from supplements, while most respondents had intakes close to or below the recommended level.

2. Sunlight Exposure

   Sunlight exposure was assessed using a standardized questionnaire evaluating frequency, duration, and body surface area exposed to sunlight.

   Table 2. Respondents' Sunlight Exposure

Variable	Mean ± SD (score)	Minimum (score)	Maximum (score)
Sun exposure	13,64 ± 8,89	0	36

   The mean sunlight exposure score among respondents was 13.64 ± 8.89, with values ranging from 0 to 36, indicating substantial variability in exposure levels. This variation may reflect differences in daily activities, occupational demands, and sun-protection behaviors, and is relevant given the role of ultraviolet B (UVB) radiation in endogenous vitamin D synthesis.

3. Plasma C-Reactive Protein (CRP) Levels

   Plasma C-reactive protein (CRP), a marker of systemic inflammation, was measured from venous blood samples.

Table 3. Respondents' CRP Levels

Variable	Mean ± SD (mg/dL)	Minimum (mg/dL)	Maximum (mg/dL)
CRP levels	516,58 ± 295,19	1,4	1.288,2

The mean CRP level among respondents was 516.58 ± 295.19 mg/dL, with values ranging from 1.4 to 1,288.2 mg/dL, indicating substantial interindividual variability. This wide range suggests differing degrees of inflammatory status among obese adults, which may be influenced by variations in metabolic conditions, lifestyle factors, and underlying subclinical inflammation.

4. Appendicular Skeletal Muscle Index (ASMI)

Appendicular Skeletal Muscle Index (ASMI), measured using bioelectrical impedance analysis (BIA), was used to assess skeletal muscle mass of the upper and lower limbs.

Table 4. Respondents' Appendicular Skeletal Muscle Index (ASMI)

Variable	Mean ± SD (kg/m²)	Minimum (kg/m²)	Maximum (kg/m²)
ASMI	54,39 ± 95,91	3	645

The mean ASMI among respondents was 4.72 ± 0.69 kg/m², with values ranging from 3.58 to 6.32 kg/m², indicating variability in muscle mass among obese adults. These differences may be influenced by factors such as age, sex, physical activity, and nutritional intake, including vitamin D status, and are relevant for evaluating the risk of reduced muscle mass and sarcopenia.

Bivariate Analysis

1. Association between Vitamin D Intake and Plasma CRP Levels

The relationship between vitamin D intake and plasma C-reactive protein (CRP) levels was examined to assess the potential anti-inflammatory role of vitamin D in obese adults. Normality testing using the Kolmogorov–Smirnov and Shapiro–Wilk tests showed that both vitamin D intake and CRP levels were normally distributed (Table 5). Therefore, Pearson's correlation test was applied.

Table 5. Results of the Normality Test of Vitamin D Intake and Plasma CRP Levels

Variable	Kolmogorov–Smirnov Sig.	Shapiro–Wilk Sig.	Distribution
Vitamin D Intake	0.078	0.055	Normal
CRP (mg/dL)	0.200*	0.070	Normal

Table 6. Results of Pearson Correlation Test between Vitamin D Intake and Plasma CRP Levels

Variable	Correlation Coefficient (r)	Sig. (2-tailed)	N
Vitamin D Intake vs. CRP (mg/dL)	–0.172	0.155	70

As shown in Table 6, vitamin D intake was weakly and negatively correlated with plasma CRP levels ($r = -0.172$), but this association was not statistically significant ($p = 0.155$). These findings indicate that vitamin D intake was not significantly associated with systemic inflammation as measured by CRP in this study population. This suggests that vitamin D intake alone may be insufficient to influence CRP levels in obese adults, as inflammation in obesity is likely driven by multiple factors such as visceral adiposity, insulin resistance, low physical activity, and oxidative stress.

2. Association between Plasma CRP Levels and ASMI

The association between plasma C-reactive protein (CRP) levels and Appendicular Skeletal Muscle Index (ASMI) was analyzed to evaluate the potential influence of systemic inflammation on skeletal muscle mass in obese adults. Normality tests indicated that both CRP and ASMI were normally distributed (Table 7), allowing the use of Pearson's correlation analysis.

Table 7. Results of the Normality Test of Plasma CRP and ASMI Levels

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Variable	Kolmogorov–Smirnov Sig.	Shapiro–Wilk Sig.	Distribution
CRP (mg/dL)	0.200*	0.070	Normal
ASMI (kg/m²)	0.200*	0.058	Normal

Table 8. Results of Pearson Correlation Test between Plasma CRP Levels and ASMI

Variable	Correlation Coefficient (r)	Sig. (2-tailed)	N
CRP (mg/dL) vs ASMI (kg/m²)	0.237*	0.048	70

As presented in Table 8, a weak but statistically significant positive correlation was found between plasma CRP levels and ASMI ($r = 0.237$; $p = 0.048$). This result suggests that higher CRP levels were modestly associated with higher ASMI values in this population. Although inflammation is generally expected to impair muscle mass, this finding may reflect the characteristics of obese adults who tend to have relatively higher muscle mass alongside varying degrees of metabolic inflammation. Other factors such as body fat distribution, physical activity, protein intake, and sex differences may also influence this relationship. Therefore, despite being statistically significant, the observed association should be interpreted cautiously within the multifactorial context of obesity-related muscle mass regulation.

3. Association between Vitamin D Intake and ASMI

The association between vitamin D intake and Appendicular Skeletal Muscle Index (ASMI) was examined to assess the role of vitamin D in maintaining skeletal muscle mass in obese adults. Normality testing showed that both vitamin D intake and ASMI were normally distributed (Table 9), allowing the use of Pearson's correlation analysis.

Table 9. Results of the Normality Test of Vitamin D Intake and ASMI

Variable	Kolmogorov–Smirnov Sig.	Shapiro–Wilk Sig.	Distribution
Vitamin D Intake	0.078	0.055	Normal
ASMI (kg/m²)	0.200*	0.058	Normal

Table 10. Results of Pearson Correlation Test between Vitamin D Intake and ASMI

Variable	Correlation Coefficient (r)	Sig. (2-tailed)	N
Vitamin D Intake vs ASMI (kg/m²)	0.004	0.973	70

As shown in Table 10, the Pearson correlation between vitamin D intake and ASMI was negligible and not statistically significant ($r = 0.004$; $p = 0.973$). This indicates that variations in vitamin D intake were not associated with differences in ASMI in this study population. These findings suggest that daily vitamin D intake alone may not be sufficient to influence skeletal muscle mass in obese adults. Other factors, including physical activity, protein intake, body fat distribution, and hormonal or genetic influences, are likely to play a more dominant role in determining muscle mass.

Multivariate Analysis Results

Multivariate analysis was performed using multiple linear regression to examine the simultaneous association of vitamin D intake and plasma C-Reactive Protein (CRP) levels with Appendicular Skeletal Muscle Index (ASMI) in obese adults at RSUI. ASMI was defined as the dependent variable, while vitamin D intake and CRP levels were independent variables. All variables were continuous, fulfilling the assumptions for linear regression analysis. The results of the multiple linear regression analysis are presented in Table 11.

Table 11. Results of Multiple Linear Regression Analysis between Vitamin D Intake and Plasma CRP Levels on ASMI

Variable	Coefficient B	Standard Error	Standard Beta	t value	*p-value*

Constant	4,72	0,099	–	47,665	<0,001
CRP (mg/dL)	$9{,}155 \times 10^{-8}$	0,000	0,268	2,172	0,033*
Vitamin D intake (mcg/day)	−0,001	0,003	−0,055	−0,449	0,655

The resulting regression equation was:

$$ASMI = 4.720 + (9.155 \times 10^{-8} \times CRP) - (0.001 \times \text{vitamin D intake})$$

The constant (4.720) represents the baseline ASMI when both independent variables are zero and serves as a statistical reference point. Plasma CRP showed a positive and statistically significant association with ASMI ($p = 0.033$), indicating that higher CRP levels were associated with slightly higher ASMI values after controlling for vitamin D intake. In contrast, vitamin D intake showed a negative but non-significant association with ASMI ($p = 0.655$), suggesting no meaningful independent effect.

Table 12. t-Test Results

Variable	Coefficient B	Standard Error	t value	*p-value*
Plasma CRP levels	$9{,}155 \times 10^{-8}$	0	2,172	0,033*
Vitamin D intake	−0,001	0,003	−0,449	0,655

Table 13. F Test Results

Model	Sum of Squares	Degrees of Freedom	Mean Square	F value	*p-value*
Regression	0,214	2	0,107	2,411	0,101
Residual	3,032	68	0,045		
Total	3,246	70			

Partial effects were confirmed through the t-test (Table 12), where CRP remained significant, while vitamin D intake did not. However, the simultaneous effect assessed by the F-test (Table 13) indicated that the overall regression model was not statistically significant ($p = 0.101$). This suggests that, together, vitamin D intake and CRP levels did not significantly predict ASMI.

Table 14. Value of the Coefficient of Determination (R^2)

Model	R	R^2	Adjusted R^2
Regression	0,257	0,066	0,038

The coefficient of determination (Table 14) showed an R^2 of 0.066, meaning that only 6.6% of the variability in ASMI was explained by the model, with an adjusted R^2 of 0.038. This indicates that most of the variation in ASMI is influenced by other factors not included in the model, such as physical activity, protein intake, body composition, and hormonal or genetic factors.

Discussion

Characteristics of Adult Obese Respondents at RSUI

Respondent characteristics are important for interpreting the relationships between vitamin D intake, plasma C-Reactive Protein (CRP) levels, and Appendicular Skeletal Muscle Index (ASMI). This study involved 70 adult obese participants across a wide age range, mostly of productive age. Age variation is relevant because increasing age is associated with low-grade chronic inflammation and a decline in skeletal muscle mass, which may influence CRP and ASMI values.

The sample was predominantly female. Sex differences are important to consider, as men and women differ in body composition, fat distribution, and hormonal profiles, which can affect inflammatory status and muscle mass. Women generally have higher body fat percentages, whereas men tend to have greater muscle mass, potentially influencing ASMI and CRP levels.

Most respondents had a higher education level and belonged to middle-to-high socioeconomic groups. Higher education and income are generally associated with better health awareness and access to nutrition and healthcare. However, the presence of obesity in this group indicates that metabolic disorders are influenced not only by socioeconomic status but also by complex lifestyle factors, including diet and physical activity. These sociodemographic characteristics therefore provide essential context for interpreting the study findings.

Sunlight Exposure in Adult Obese Respondents at RSUI

Sunlight exposure is a key factor in endogenous vitamin D synthesis through ultraviolet B (UVB) radiation. Although this study focused on dietary vitamin D intake, variations in sunlight exposure may influence overall vitamin D status and affect the interpretation of its relationship with CRP and ASMI.

The results showed substantial variation in sunlight exposure among respondents, ranging from minimal to relatively high exposure. This variability is likely influenced by daily activities, occupation, outdoor habits, and the use of sun protection. Among individuals of productive age, indoor work and sedentary lifestyles may limit direct sunlight exposure, even in a tropical setting.

In obese individuals, the effectiveness of vitamin D synthesis and availability may be further reduced, as excess adipose tissue sequesters fat-soluble vitamin D, lowering its bioavailability. Combined with lower physical activity and limited outdoor exposure, this condition may contribute to suboptimal vitamin D status despite adequate sunlight exposure.

Vitamin D Intake in Adult Obese Patients at RSUI

The mean vitamin D intake among respondents was 54.39 ± 95.91 µg/day, with a wide range (3–645 µg/day), indicating a highly uneven distribution. The large standard deviation suggests that the high mean value was influenced by a small number of respondents with very high intake, likely from supplementation. In contrast, most respondents had vitamin D intake below the recommended dietary allowance of 15 µg/day, indicating inadequate intake among the majority of obese adults.

Low vitamin D intake may be related to limited consumption of vitamin D–rich foods, low sunlight exposure due to predominantly indoor activities, and lifestyle factors. This supports evidence that obesity is often accompanied by micronutrient deficiencies, including vitamin D, despite excessive energy intake. These findings are consistent with (Krajewska et al., 2022), who reported low 25(OH)D levels and higher CRP concentrations among overweight and obese children and adolescents, with significant CRP reduction after vitamin D supplementation. Although the average intake in the present study appeared high, it did not reflect adequacy in most respondents, highlighting persistent inequality in vitamin D intake among obese adults.

Similar findings were reported by (Nari et al., 2020), who found that CRP levels were more strongly associated with body fat distribution and BMI than with vitamin D intake. Studies by (Suyoto & Aulia, 2019) also showed associations between hs-CRP, skeletal muscle mass, and body fat composition without emphasizing vitamin D. Overall, these findings suggest that low vitamin D intake alone is insufficient to reduce inflammation or improve muscle mass without addressing other factors such as physical activity, overall diet quality, and metabolic status.

Plasma C-Reactive Protein (CRP) Levels in Adult Obese Patients at RSUI

The mean plasma CRP level was 516.58 ± 295.19 mg/dL, with values ranging from 1.4 to 1,288.2 mg/dL. Compared with the normal reference value (<0.3 mg/dL), most respondents exhibited elevated CRP levels, indicating low- to moderate-grade systemic inflammation commonly associated with obesity.

Elevated CRP levels can be explained by increased visceral adiposity, which promotes the production of proinflammatory cytokines such as IL-6 and TNF-α, stimulating hepatic CRP synthesis. Insulin resistance, oxidative stress, low physical activity, and unhealthy dietary patterns may further exacerbate inflammation. These findings are consistent with (Nari et al., 2020), who reported significant associations between hs-CRP, BMI, and waist circumference, particularly among women. Similarly, (Suyoto & Aulia, 2019) found correlations between hs-CRP, skeletal muscle mass, and body fat components in the Indonesian population.

In line with (Krajewska et al., 2022), who demonstrated significant reductions in CRP following vitamin D supplementation in overweight and obese youth, the elevated CRP levels observed in this study reinforce the role of chronic low-grade inflammation as a key metabolic feature of obesity. Although no significant association between vitamin D intake and CRP was found in this study, these results underscore the importance of comprehensive interventions, including balanced nutrition, increased physical activity, and effective weight management, to reduce inflammation in obese adults.

Appendicular Skeletal Muscle Index (ASMI) in Adult Obese Patients at RSUI

The mean ASMI of respondents was 4.72 ± 0.69 kg/m² (range: 3.58–6.32 kg/m²). According to the Asian Working Group for Sarcopenia (AWGS) criteria, most respondents were classified as having normal muscle mass, while a small proportion fell into the low ASMI category, indicating a risk of sarcopenia. This suggests that although respondents were obese, the majority still had relatively preserved skeletal muscle mass. However, the observed variation in ASMI reflects differences in age, sex, physical activity, and macronutrient intake, particularly protein.

Sex and age were important contributors to ASMI variation. Men generally have higher muscle mass than women due to hormonal and activity-related factors, while age-related muscle loss may place older adults at higher risk of reduced ASMI. The predominance of female respondents and the wide age range may therefore have influenced the ASMI distribution. Consistent with (Suyoto & Aulia, 2019), inflammation has been shown to correlate with skeletal muscle mass and body fat components, suggesting a potential catabolic effect of chronic inflammation. However, in this study, no significant association between CRP and ASMI was observed prior to sex adjustment, indicating that factors such as hormonal differences, protein intake, and physical activity may play a more dominant role.

Findings from (Krajewska et al., 2022) suggest that improved vitamin D status may indirectly support muscle maintenance through inflammation reduction. Although no significant association between vitamin D intake and ASMI was found in this study, adequate micronutrient intake, regular physical activity, and inflammation control remain essential for preserving muscle mass in obese adults.

Relationship between Vitamin D Intake and Plasma C-Reactive Protein (CRP)

This study found no statistically significant association between vitamin D intake and plasma CRP levels in adult obese patients at RSUI ($r = -0.006$; $p = 0.959$). The near-zero negative correlation indicates that differences in vitamin D intake were not associated with variations in systemic inflammation as measured by CRP. These results suggest that daily vitamin D intake alone is insufficient to modulate inflammatory status in obese adults.

The absence of an association can be explained by the complex inflammatory mechanisms in obesity, characterized by excess visceral fat and increased production of proinflammatory cytokines such as IL-6 and TNF-α, which stimulate hepatic CRP synthesis. Other contributing factors, including insulin resistance, oxidative stress, low physical activity, smoking, and high saturated fat intake, may overshadow the potential anti-inflammatory effects of vitamin D.

These findings differ from (Krajewska et al., 2022), who reported significant CRP reductions following vitamin D supplementation in overweight and obese children and adolescents. Such differences may be attributed to study design, vitamin D source and dosage, participant characteristics, and metabolic or genetic factors. In contrast, studies by (Suyoto & Aulia, 2019) and (Nari et al., 2020) demonstrated that CRP levels were more closely related to body fat distribution and muscle mass than to specific nutrient intake, including vitamin D.

Overall, these results reinforce the multifactorial nature of inflammation in obesity, indicating that improving vitamin D intake alone is unlikely to reduce CRP levels without comprehensive lifestyle and metabolic interventions.

Relationship between Vitamin D Intake and Appendicular Skeletal Muscle Index (ASMI)

This study found no statistically significant association between vitamin D intake and ASMI among obese adults at RSUI ($r = 0.004$; $p = 0.973$). The near-zero correlation indicates that variations in vitamin D intake were not accompanied by meaningful changes in skeletal muscle mass. Although vitamin D is known to influence muscle function through the vitamin D receptor (VDR) and protein synthesis, these findings suggest that other factors—such as protein intake, physical activity level, hormonal status, aging, and chronic low-grade inflammation—play a more dominant role in determining muscle mass in obese adults.

These results differ from findings by (Krajewska et al., 2022), who reported that vitamin D supplementation reduced inflammation and may indirectly support muscle health in overweight and obese children and adolescents. Differences in age groups, study design, vitamin D assessment, and confounding factors such as protein adequacy and physical activity may explain the discrepancy. Similarly, (Suyoto & Aulia, 2019) reported an association between hs-CRP and skeletal muscle mass but did not emphasize vitamin D intake, further supporting the notion that the effect of vitamin D on muscle mass is not direct. Overall, these findings indicate that improving vitamin D intake alone is insufficient to increase ASMI, and comprehensive nutritional and lifestyle interventions are required.

Relationship between Plasma C-Reactive Protein (CRP) and Appendicular Skeletal Muscle Index (ASMI)

A statistically significant but weak positive association was observed between plasma CRP levels and ASMI in obese adults at RSUI ($r = 0.237$; $p = 0.048$). Although this relationship reached statistical significance, the low correlation coefficient suggests minimal clinical relevance, indicating that higher CRP levels were only slightly associated with higher ASMI values. This finding implies that systemic inflammation, as reflected by CRP, does not directly or strongly influence skeletal muscle mass in this population.

Physiologically, chronic inflammation in obesity is generally associated with muscle catabolism through increased proinflammatory cytokines such as IL-6 and TNF-α, which inhibit muscle protein synthesis. Therefore, the positive association observed in this study appears contrary to established theory. This discrepancy may be explained by confounding factors, particularly sex differences, as men typically have higher ASMI values than women. Given that most respondents were female, sex distribution may have influenced the observed relationship. This contrasts with findings by (Suyoto & Aulia, 2019), who reported a negative association between hs-CRP and skeletal muscle mass in adults with type 2 diabetes, and with (Nari et al., 2020), who highlighted the strong role of body fat distribution in CRP elevation.

Overall, these findings suggest that while CRP is related to ASMI, its direct impact is limited and likely overshadowed by other determinants such as sex, physical activity, protein intake, and hormonal factors. Maintaining muscle mass in obese adults therefore requires multifactorial interventions beyond inflammation control alone.

Effects of Vitamin D Intake and Plasma C-Reactive Protein (CRP) on Appendicular Skeletal Muscle Index (ASMI)

Multivariate analysis showed that plasma C-Reactive Protein (CRP) levels had a significant effect on Appendicular Skeletal Muscle Index (ASMI) in obese adults. This finding is consistent with (Suyoto & Aulia, 2019), who reported an association between hs-CRP levels and skeletal muscle mass in adults with type 2 diabetes mellitus, indicating that inflammatory markers are linked to changes in muscle mass under metabolic disorders.

The role of systemic inflammation in obesity is further supported by (Nari et al., 2020) in Korea, who found that body mass index and waist circumference were associated with elevated hs-CRP levels, particularly in women. These results reinforce the notion that chronic low-grade inflammation in obesity contributes to alterations in muscle metabolism, thereby affecting peripheral muscle mass.

In contrast, vitamin D intake did not show a significant effect on ASMI in the multivariate analysis. This differs from the findings of (Krajewska et al., 2022), who reported that 25-hydroxyvitamin D levels were associated with reduced CRP and increased anti-inflammatory cytokines in overweight and obese children. Differences in age groups and study design may explain this discrepancy, as the present study involved adults and used a cross-sectional design, whereas Krajewska et al. employed a cohort approach.

Finally, the reliability of CRP measurements in this study is supported by (Aziz et al., 2003), who demonstrated that specimen type, processing time, and storage conditions do not significantly affect CRP concentrations. Therefore, the observed association between plasma CRP and ASMI likely reflects true biological conditions rather than technical laboratory variations.

CONCLUSION

This study assessed vitamin D intake, plasma C-Reactive Protein (CRP) levels, Appendicular Skeletal Muscle Index (ASMI), and the relationships among these variables in obese adults at Universitas Indonesia Hospital.

The findings indicate that most obese adults had inadequate vitamin D intake and elevated plasma CRP levels, reflecting the presence of low- to moderate-grade systemic inflammation commonly associated with obesity. Although ASMI values were generally within the normal range, a small proportion of participants showed low ASMI, suggesting a potential risk of muscle mass decline influenced by factors such as age, sex, physical activity, and macronutrient intake.

No significant association was found between vitamin D intake and plasma CRP levels or between vitamin D intake and ASMI, suggesting that vitamin D intake alone does not directly influence systemic inflammation or skeletal muscle mass in obese adults. In contrast, plasma CRP levels showed a weak but statistically significant positive association with ASMI and exerted a more evident influence on ASMI than vitamin D intake. However, this relationship may be affected by confounding factors, particularly sex differences, physical activity, and protein intake. Overall, these findings emphasize that obesity management requires a comprehensive approach addressing dietary quality, physical activity, and metabolic and inflammatory conditions, rather than focusing solely on vitamin D intake.

Recommendations

Future studies are recommended to assess serum vitamin D [25(OH)D] levels to better reflect vitamin D status and to apply longitudinal or experimental designs to clarify causal relationships between vitamin D, inflammation, and muscle mass. Including variables such as physical activity, protein intake, and hormonal status would provide a more holistic understanding.

For clinicians and nutrition professionals, obesity management should not only target weight reduction but also consider inflammatory status and skeletal muscle health. Vitamin D supplementation should be based on serum levels and combined with lifestyle interventions, including adequate protein intake and regular physical activity.

Health institutions are encouraged to provide routine body composition assessments and to implement nutritional and inflammatory screening programs for obese patients to detect early risks of sarcopenia and metabolic complications. For the general public, increased awareness of balanced nutrition, sufficient sunlight exposure, and regular physical activity is essential, as obesity is closely linked to chronic inflammation and reduced muscle quality that may impair physical and metabolic function.

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