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Original Article

# Anthropometric Measurements and Body Composition of Indonesian Patients with Type 2 Diabetes are Associated with Inflammation, Independent of Sex and Disease Duration

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## Abstract

**Introduction:** Abnormal body composition, such as a high percentage of body fat, triggers an inflammatory reaction, which links the association between obesity and diabetes complications. Females, in general, have higher body fat, which may play a part in elevating cardiovascular disease risk. This study aimed to study the association between several anthropometric measurements and inflammatory markers in individuals with type 2 diabetes mellitus. We intended to confirm if this association is independent of sex and duration of diabetes. **Material and Methods:** People with type 2 diabetes mellitus were recruited from primary health care centers in Sleman, Indonesia. Several anthropometric measurements were performed, followed by an analysis of plasma high-sensitivity C-reactive protein. A comparison of anthropometric measurements was made between individuals with (high-sensitivity CRP<3 mg/L) and without inflammation (high-sensitivity CRP≥3mg/L). Spearman correlation analysis was conducted to learn the association between anthropometric measurements with the high-sensitivity CRP level. Adjustments were made for sex and duration of diabetes. **Results:** Differences were found on weight, BMI, hip circumference, upper-arm circumference, and wrist circumference. Among body composition measurements, total body fat, subcutaneous fat (whole body, trunk and leg), and visceral fat were different between groups. Bodyweight, BMI, waist circumference, hip circumference, arm circumference, neck circumference, and wrist circumference were significantly correlated with high-sensitivity CRP values. **Conclusion:** Associations were found between the inflammatory marker and anthropometric measurements, independent of sex and disease duration.

Keywords: Diabetes, inflammation, C-reactive protein, anthropometry, body composition

## Introduction

Inflammation is a natural mechanism against infection and injury. Inflammation is initiated and intensified in a short time following the insults, which can sustain for days. In a normal condition, the inflammatory response is swiftly terminated upon clearance of infection and injurious mediators. This careful control of complex inflammatory signaling cascades minimizes tissue damage as a consequence of free radicals released during inflammation [1].

A milder and sustained version of inflammation has been extensively studied within past decades, which is linked to several conditions, including cardiovascular diseases [2], cancer [3], Alzheimer's disease [4], sarcopenia [5] and type 2 diabetes mellitus [6]. This phenomenon is commonly termed chronic, low-grade inflammation, or metabolic inflammation (metaflammation). It drifts from the classic type of inflammation, as it lacks calor, dolor, rubor, and tumor. In addition to that, there is no substantial increase in basal energy expenditure observed [7]. A higher degree of chronic

inflammation was observed with increasing age. This aging-associated chronic inflammation or inflammaging may result from genetic factors, central adiposity, leaky gut, gut dysbiosis, mitochondrial dysfunction, and chronic infection [8].

In type 2 diabetes mellitus (T2DM), inflammation may be triggered by several distinct mechanisms. Excessive adiposity increases the concentration of Interleukin-6 (IL-6) in the circulation [9, 10]. IL-6 induces an acute phase response, which is followed by the release of acute phase mediators such as serum amyloid A (SAA), haptoglobin, fibrinogen, and C-reactive protein (CRP) from the liver [11]. Poor glycemic control may lead to the formation of advanced glycation end products (AGEs), which can bind to the receptor of AGE (RAGE). RAGE ligation on vascular or immune cells triggers several signal transduction cascades leading to activation of NF-κB [12] and transcription of several inflammatory cytokines including IL-1, IL-2, IL-6, IL-8, IL-12 and TNF-α [13]. AGE formation is accelerated due to inflammation, oxidative stress, and aging [14].

There are differences between genders in terms of the risk and outcome of diabetes. These differences may be caused by organs' systemic response to a difference in sex chromosome and gender-specific expression of genes in the autosomes and sex-specific hormones [15]. These differences lead to phenotypic differences between genders, including body composition. Body fatness, which is commonly higher in females, is associated with diabetes outcomes. According to the UK Biobank Study, which investigated the differences of anthropometric adiposity measures (weight, waist and hip circumference, BMI, and body fat) between individuals with and without diabetes, the measure differences were higher in female participants [16]. Adiposity is positively correlated with chronic inflammation [17], which contributes to the sex-associated difference in inflammation state. Indeed, a previous study involving a large number of female and male participants with new-onset diabetes (13,676 and 7,809, respectively) showed that high-sensitivity C-reactive protein (hs-CRP) concentration tended to be higher in females (1.85 ±3.09 vs. 1.47±2.33; $p<0.000001$) [18]. In a systematic review of over five-million participants, women with diabetes have a 58% higher risk of developing coronary heart disease. Compared with their male counterparts, females with diabetes also have a 30% greater risk of cardiovascular disease. In addition to that, a 13% greater all-cause mortality risk is attributable to females with diabetes [19].

Increased risk of diabetes complications is also associated with a longer duration of diabetes. In a previous study, the duration of diabetes is associated with death, microvascular, and macrovascular events [20]. A Sri Lankan study showed that the duration of diabetes >10 years was associated with a doubled risk of microvascular complication and diabetic foot [21]. The risk of infectious diseases, such as infective endocarditis, is also elevated with longer duration of diabetes. A three-times higher risk of infective endocarditis is seen in individuals that have diabetes for more than 15 years compared with 0-5 years [22].

CRP, as a marker of inflammation, was shown to be associated with several diseases risk. CRP can be categorized into lower (<1 mg/L), moderate (1-3 mg/L), and higher (>3 mg/L), which represent a relative risk of heart disease [23]. In a meta-analysis using a fixed-effect model, the subjects in the highest category of hs-CRP had twice the risk of cardiovascular mortality. In the same study, cancer risk was increased by 25% for those in the highest category of hs-CRP [3].

In this study, we aimed to investigate the factors that may be related to inflammation in patients with type 2 diabetes mellitus, in this case, anthropometric measurements, muscle strength, and body composition. Associations were evaluated controlling for sex and duration of disease.

## Material and Methods

### Participants

Participants were recruited from two-state primary health care centers and one private primary care clinic in Sleman, Indonesia. At the time, they were participating in a Chronic Disease Management Program, an activity organized at primary health care level to promote health to people with chronic diseases including physical activity, health monitoring, medical consulting, psychological services, nutrition counseling, physiotherapy, and laboratory tests [24]. All male and female individuals diagnosed with type 2 diabetes were recruited to this study. Participation in this study was entirely voluntary. This study was approved by the Medical and Health Research Ethics Committee (MHREC), Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada (No. KE/FK/1253/EC/2018). All subjects gave written informed consent to participate in the study.


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## Anthropometric Measurements

We measured participants' body weight, height, waist circumference, hip circumference, upper arm circumference, neck circumference, wrist circumference, handgrip strength, and triceps skinfold. All measurements were performed in compliance with the Body Measurements (Anthropometry) protocol published by the U.S. Center for Disease Control and Prevention [25]. Bioelectrical impedance analysis (BIA) was also performed to estimate whole body, trunk, arm and leg subcutaneous fat and muscle mass, visceral fat, and total body fat (Omron HBF 375, USA).

## Laboratory method

Venipuncture by a phlebotomist was carried out for all subjects after 8 hours of fasting, using vacuum extraction tube systems. The blood in the tube containing EDTA was centrifuged at 2000 x g for 15 minutes, followed by the transfer of the supernatant into microtubes. The tubes were then frozen at 20°C until further analysis. Plasma high-sensitivity C-reactive protein analysis was performed using the Enzyme-linked immunosorbent assay (ELISA) method as instructed in the provided manual (Calbiotech, USA). The concentration of hs-CRP at or above 3 mg/L was considered inflammation.

## Data analysis

Participants were divided into two groups according to inflammation status (hs-CRP <3 vs. ≥3 mg/L). Anthropometric measurement differences between groups were analyzed using the General Linear Model. Statistical significance was determined in three models: unadjusted, adjusted for sex, and adjusted for sex and duration of diabetes. Besides, partial Spearman's Correlation was used to analyze the association between anthropometric measurements with hs-CRP, adjusted for sex, and duration of diabetes. A P-value of <0.05 was considered statistically significant.

## Results

Subject characteristics are shown in Table 1. Female participants were three times as many as their male counterparts. The majority (77.9%) of the subjects were >55 years old. The number of subjects with a duration of diabetes of <5 years, 5-10 years, and >10 years was nearly proportional (40.7% vs. 31.4% vs. 27.9%, respectively). According to BMI, most of the subjects fell into the overweight category (41.9%). Obesity was present in 20.9% of all participants. More than half (58.1%) of the subjects had an inflammation state, as indicated by hs-CRP values (≥3).

Table 1: Subject Characteristics (n=86).

| Variable | n (%) |
|---|---|
| **Age** | |
| 18-35 y | 1 (1.2) |
| 36-55 y | 18 (20.9) |
| >55 y | 67 (77.9) |
| **Sex** | |
| Male | 23 (26.7) |
| Female | 63 (73.3) |
| **Duration of Diabetes** | |
| <5y | 35 (40.7) |
| 5-10y | 27 (31.4) |
| >10y | 24 (27.9) |
| **BMI** | |
| Underweight | 2 (2.3) |
| Normal | 30 (34.9) |
| Overweight | 36 (41.9) |
| Obesity | 18 (20.9) |
| **hs-CRP serum concentration** | |
| <3 mg/L | 36 (41.8) |
| ≥3 mg/L | 50 (58.1) |

Table 2 shows the anthropometric measurements, muscle strength, and body composition in subjects classified as being in a non-inflammation and inflammation state. Patients in the inflammation state had higher body weight in corrected models (64.56 ± 11.19 vs. 59.67 ± 12.61; p2=0.02, p3=0.03). Using BMI as a comparison, the difference was significant across all models (27.44 ± 4.17 vs. 25.24 ± 4.21; p1=0.01, p2=0.02, p3=0.01). Among all the body circumference measurements, only neck circumference had no significant difference between the groups. No significant difference in the wrist circumference was observed, only in the unadjusted model. However, after adjustment for sex or sex and disease duration, the differences between groups were significant (p2=0.02, p3=0.01). Regarding

Table 2: Comparison of anthropometric measurements between the group with and without inflammation (n=86).

| Variables | hs-CRP serum concentration | | p-value | | |
|---|---|---|---|---|---|
| | <3 mg/L | ≥3 mg/L | Model 1[b] | Model 2[c] | Model 3[d] |
| **Weight (kg)** | 59.67 ± 12.61 | 64.56 ±11.19 | 0.06 | 0.02* | 0.03* |
| **Height (cm)** | 153.30 ± 8.06 | 153.3 1±7.27 | 0.99 | 0.51 | 0.73 |
| **BMI (kg/m2)** | 25.24 ± 4.21 | 27.44 ±4.17 | 0.01* | 0.02* | 0.01* |
| **Waist circumference (cm)** | 86.53 ± 10.90 | 90.59 ±10.0 | 0.07 | 0.05 | 0.03* |
| **Hip circumference (cm)** | 94.14 ± 12.40 | 99.43 ± 9.08 | 0.02* | 0.02* | 0.05* |
| **Upper arm circumference (cm)** | 27.51 ± 3.89 | 29.51 ± 3.95 | 0.02* | 0.02* | 0.03* |
| **Neck circumference (cm)** | 34.53 ± 4.19 | 35.38 ± 4.12 | 0.35 | 0.13 | 0.08 |
| **Wrist circumference (cm)** | 15.16 ± 1.22 | 15.67 ± 1.33 | 0.07 | 0.02* | 0.01* |
| **Handgrip strength (kg)** | 18.48 ± 14.19 | 19.79 ± 11.15 | 0.63 | 0.36 | 0.61 |
| **Triceps skinfold (cm)** | 19.22 ± 6.97 | 21.75 ± 8.50 | 0.14 | 0.18 | 0.17 |
| **Total body fat (%)** | 32.75 ± 6.44 | 35.81 ± 5.34 | 0.01* | 0.01* | 0.01* |
| **Visceral fat (%)** | 10.44 ± 6.02 | 12.86 ± 6.18 | 0.07 | 0.03* | 0.02* |
| **Whole subcutaneous fat (%)** | 26.61 ± 7.47 | 29.92 ± 6.81 | 0.03* | 0.01* | 0.02* |
| **Trunk subcutaneous fat (%)** | 23.91 ± 6.64 | 26.95 ± 6.14 | 0.03* | 0.01* | 0.01* |
| **Arm subcutaneous fat (%)** | 39.84 ± 12.39 | 43.42 ± 11.29 | 0.16 | 0.09 | 0.12 |
| **Leg subcutaneous fat (%)** | 34.87 ± 9.39 | 39.16 ± 9.09 | 0.03* | 0.01* | 0.01* |
| **Total muscle mass (%)** | 23.58 ± 3.42 | 22.78 ± 2.99 | 0.25 | 0.34 | 0.23 |
| **Trunk muscle mass (%)** | 17.31 ± 3.30 | 16.54 ± 2.65 | 0.23 | 0.32 | 0.25 |
| **Arm muscle mass (%)** | 26.81 ± 5.89 | 25.00 ± 5.63 | 0.15 | 0.12 | 0.14 |
| **Leg muscle mass (%)** | 37.48 ± 5.52 | 36.96 ± 4.62 | 0.64 | 0.94 | 0.98 |

Note: a unadjusted mean ± SD; b unadjusted p-value; c p-value adjusted for sex; d p-value adjusted for sex and duration of diabetes; * p<0.05

waist circumference, statistical significance was shown only after adjustment for sex and duration of diabetes (p3=0.03). No difference was found on triceps skinfold. In body composition, whole body, trunk, arm, and leg skeletal muscle showed no significant difference between groups. However, the group with higher hs-CRP showed overall higher body fat, except for the arm subcutaneous fat.

Several anthropometric measurements were correlated with the hs-CRP level, including body weight, BMI, waist circumference, hip circumference, and arm circumference. The associations remained significant even after adjustment for sex and duration of diabetes (Figure 1). Neck and wrist circumference only become significant after being adjusted. Arm muscle mass is the only muscle mass measurement that correlated with hs-CRP. All measures of percent body fat were correlated with hs-CRP (Figure 2).

## Discussion

Being widely used for measurement of the nutritional status, BMI should be interpreted cautiously for its lack of accuracy to predict body fatness [26]. Several efforts have been made to create an alternative of BMI with comparable practicality yet perform better in predicting body fat mass. Waist circumference was shown to be a better predictor of adiposity [27] and mortality risk [28]. Recently studied in the United States, relative fat mass (RFM), calculated from height, waist circumference, and sex, predicted whole-body fat percentage


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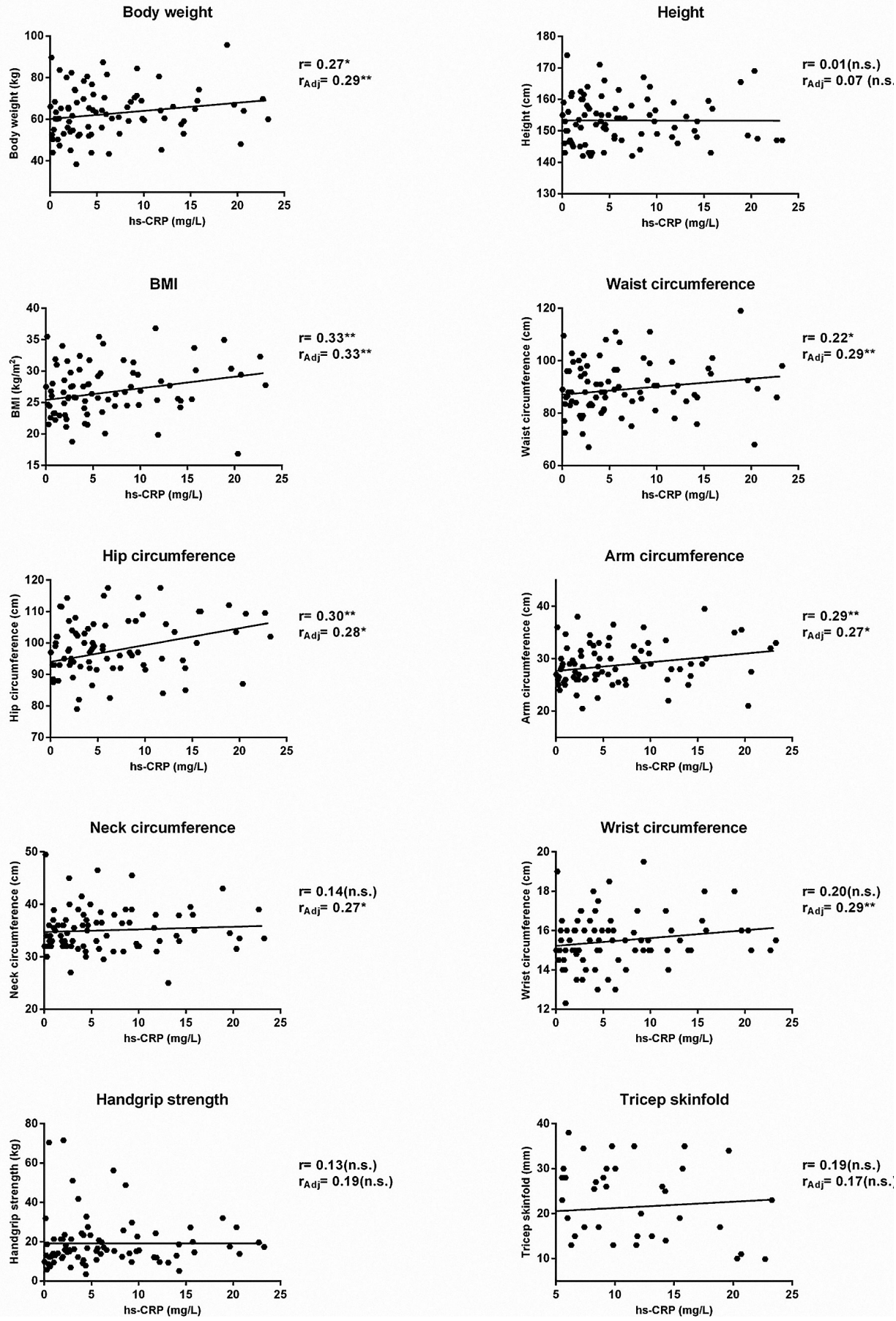


Figure 1: Correlation between anthropometric measurements and handgrip strength with hs-CRP concentration. r: Spearman's rank correlation coefficient, rAdj: correlation coefficient adjusted for sex and duration of diabetes, * $p<0.05$, ** $p<0.01$, (n.s.) no statistically significant.

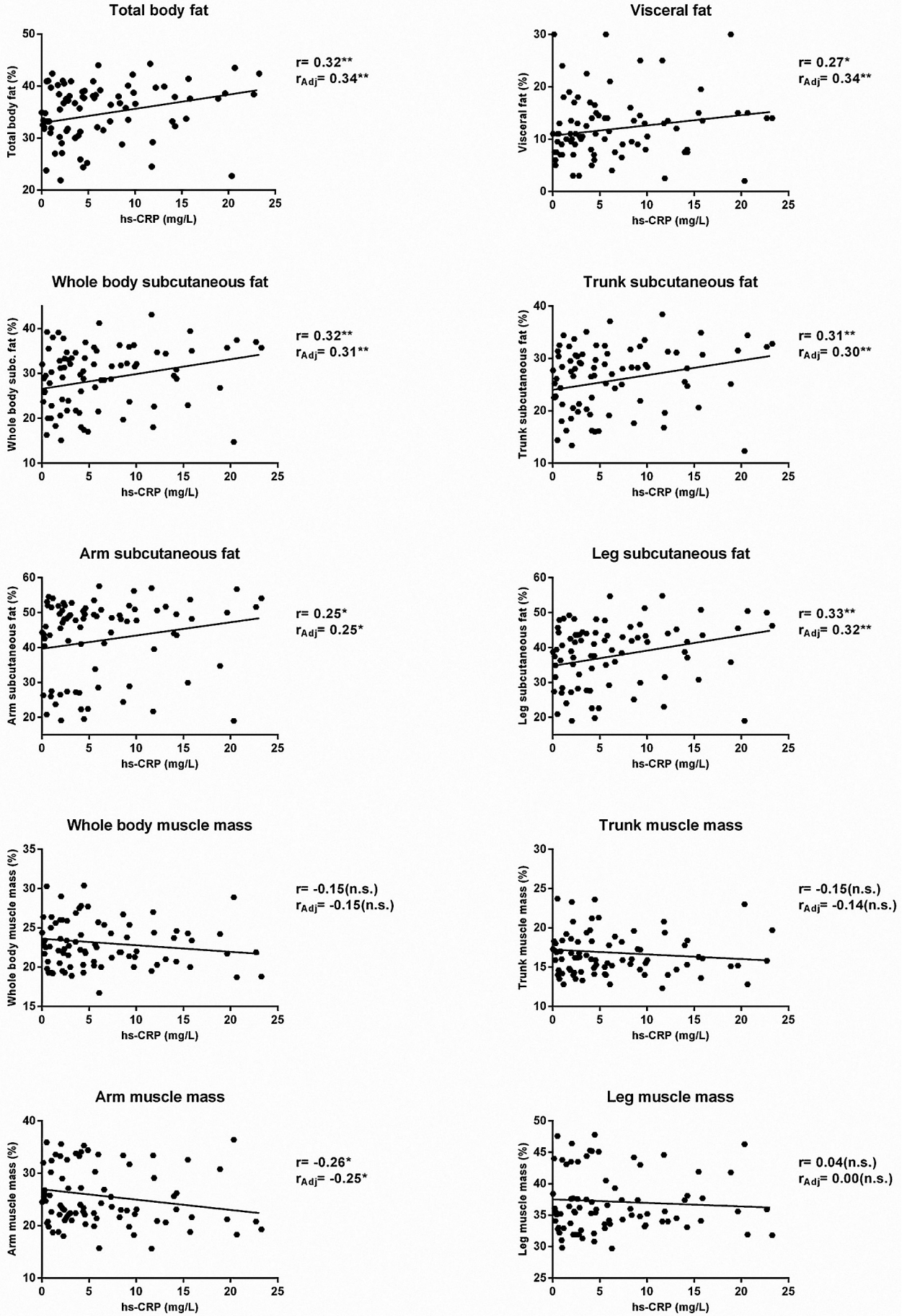


Figure 2: Correlation between body compositions with hs-CRP concentration. r: Spearman's rank correlation coefficient, rAdj: correlation coefficient adjusted for sex and duration of diabetes, * p<0.05, ** p<0.01, (n.s.) no statistically significant.


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better than BMI [29]. Among non-obese individuals, abdominal obesity is related to a high level of CRP independent of BMI [30]. However, the results of our study showed that the adjusted correlation of hs-CRP with BMI is similar to that of a more reliable inflammation predictor such as total, subcutaneous, and visceral body fat. This may indicate that for a population under investigation, BMI is as powerful as other better indicators in predicting inflammation.

Obesity is more prevalent in adults with T2DM compared with the general population. Data obtained from the 1999–2002 National Health and Nutrition Examination Survey (NHANES) indicated that in the United States, 85% of adults with T2DM patients are obese or overweight. Excluding the overweight, there are 54% obese adults among them [31]. In the same survey, the prevalence of adults with overweight and obesity in the US is 35% and 30%, respectively [32]. In Saudi Arabia, the prevalence of obesity in healthy adults and adults with diabetes was 12.05 and 20.68%, respectively [33]. It seems that the prevalence of obesity in people with diabetes was double compared to the general population. The increase of year by year diabetes prevalence was associated with the increase of obesity, not overweight prevalence [34].

Body fatness is associated with diabetes complications, which may be mediated by inflammatory processes [17]. Having similar BMI, diabetes was associated with nearly three times the risk of high percentage body fat (female: >28%; male: >20%) among Iraqi people [35]. This may partially explain why inflammatory markers such as hs-CRP, IL-6, and TNF-α tend to increase in people with diabetes [36]. Elevated pro-inflammatory cytokines levels are associated with diseases such as atherosclerosis [37], coronary heart disease [38], colorectal, and gastric cancers [39], and chronic renal diseases [40]. While inflammation is consistently associated positively with complications, the role of obesity in these diseases is more complicated. Acting as a risk factor for de novo kidney failure, obesity is associated with a lesser mortality rate in hemodialysis patients [41]. An inversed correlation between adiposity and the risk of retinopathy was observed [42, 43]. This suggests a paradoxical situation considering that inflammation, which is linked to body fatness, was positively associated with diabetic retinopathy [44].

Muscle mass was associated with a lower risk of developing T2DM [45]. Low muscle mass was found to increase the risk of all-cause mortality in the 11,687 participants of the 1999–2004 NHANES. Among people with obesity, those with low muscle mass have a 2.5 times higher risk of mortality than those with preserved muscle mass [46]. There is a high prevalence of low muscle mass among patients with T2DM. A Korean study conducted in newly diagnosed and drug-naive T2DM subjects showed that 12% had low muscle mass, and 8% had low muscle mass with abdominal obesity. Low muscle mass in this study was defined as appendicular skeletal muscle mass (ASM) ÷ height$^2$ of 2 SD below the mean value of the young reference group [47]. Among people with T2DM, low muscle mass is associated with insulin resistance [48, 49]. Low muscle mass was also associated with hyperglycemia in diabetes mellitus [50]. Inflammation contributes to muscle atrophy, possibly via impaired insulin signaling, which subsequently blunts Akt kinase activity [51]. It was observed that Akt activity in response to insulin was suppressed by 34% [52]. Reduced Akt activation results in phosphorylation of the FoxO transcription factors and transcription of MuRF1 and Atrogin-1, which result in muscle protein degradation [51]. In our study, inflammation is negatively correlated with arm muscle mass.

Measurements of wrist circumference were found to be correlated with inflammation in our study. Wrist circumference is used as a measurement to determine body frame size.

A recent study conducted in obese children suggested that wrist circumference is a biomarker of adipose tissue dysfunction and is a cardiovascular risk factor. Wrist circumference was shown to independently associated with the adiponectin-leptin ratio [53]. In a different study, wrist circumference was significantly correlated with metabolic syndrome by IDF (r=0.158), NCEPT-ATPIII (r=0.184), Cook's (r=0.197), and De Ferranti's (r=0.237) definition [54]. Most of the studies evaluating wrist circumference only involved children; therefore, more studies in the adult population should be conducted [55]. Among Ghanaian female patients with T2DM, wrist circumference was an independent predictor of metabolic syndrome [56]. The association between wrist circumference and the risk of cardiovascular disease may be related to anatomical anomalies in the heart. Wrist circumference is positively correlated with left ventricular dimensions and mass and epicardial adipose tissue in overweight children. The strongest association was found between wrist circumference and left ventricular end-diastolic dimension (r=0.73; p<0.0001). The association of left ventricular end-diastolic dimension with wrist circumference was markedly better than that with BMI (r=-0.04, p=NS) [57].

## Conclusion

We found that sex and duration of diabetes had a limited impact on the association between anthropometric measurements and inflammation.

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## Conflict of Interest

The authors declare no conflict of interest.

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