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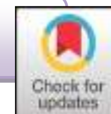

THE ASSOCIATION BETWEEN BODY MASS INDEX AND VISCERAL FAT AREA WITH CARDIOMETABOLIC RISK STRATIFICATION IN THE INDUSTRIAL WORKERS

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ABSTRACT

Background:
Body mass index (BMI) is widely used in occupational health screening but does not account for fat distribution and may misclassify metabolic risk. Visceral fat area (VFA) may provide additional insight into cardiometabolic risk, particularly in physically active industrial populations. This study aimed to evaluate the comparative association of BMI and VFA with cardiometabolic abnormalities and to assess whether VFA improves risk stratification in an industrial workforce.
Methods: A cross-sectional study was conducted among 108 industrial workers undergoing occupational health surveillance. Body composition was assessed using bioelectrical impedance analysis. Cardiometabolic abnormality was defined as ≥1 of the following: elevated blood pressure, hypertriglyceridemia, low HDL cholesterol, dysglycemia, or corresponding medication use. BMI was categorized using Asian-Pacific cutoffs (≥23 kg/m^2), and VFA as high (≥100 cm^2). Associations were analyzed using chi-square tests and multivariable logistic regression adjusted for age and sex. Sensitivity analysis was performed within a ±30-day measurement interval.
Results: Among workers with BMI ≥23 kg/m^2, those with high VFA had a significantly higher prevalence of cardiometabolic abnormalities (82.5% vs. 48.9%, p<0.001). High VFA was independently associated with increased odds of abnormality (OR 6.66, 95% CI 2.30–19.31, p<0.001), whereas BMI was not independently associated. Results remained consistent in sensitivity analysis.
Conclusion: VFA improves cardiometabolic risk stratification beyond BMI and provides a more actionable basis for fitness-for-work assessment in industrial settings.

Keywords: *body mass index, cardiometabolic risk, occupational health, risk stratification, visceral fat area*

INTRODUCTION

Periodical medical examination (PME) is a foundational component of occupational health surveillance, aimed at identifying workers at risk for chronic non-communicable diseases. Body mass index (BMI) is the most widely utilized metric for obesity screening due to its simplicity and association with mortality [1]. However, BMI is inherently limited by its inability to differentiate between adipose tissue and fat-free mass, nor does it account for the anatomical distribution of body fat. Consequently, BMI may misclassify metabolic risk in individuals with heterogeneous body composition [2,3].

Visceral fat area (VFA) reflects central adiposity and has been consistently associated with metabolic abnormalities, including insulin resistance, dyslipidemia, and hypertension [4-6]. While both BMI and VFA are utilized in various health assessments, their relative utility in identifying cardiometabolic risk within specific occupational cohorts, such as industrial workforces, remains to be fully characterized [7]. Industrial populations often possess diverse body compositions, including higher proportions of skeletal muscle mass due to the physical demands of their roles, which can further confound BMI-based risk assessments [8].

This study evaluates the comparative association of BMI and VFA with cardiometabolic abnormalities and examines whether the inclusion of VFA improves risk stratification beyond conventional BMI screening in an active industrial workforce.

MATERIAL AND METHODS

Study Design and Population

A cross-sectional study was conducted at an oil and gas company in Indonesia between July 2024 and December 2025 among 108 workers with complete anthropometric, body composition, and laboratory measurements.

This study was conducted using a retrospective analysis of secondary data derived from routine occupational health surveillance records. All data were fully anonymized prior to analysis. The study was conducted in accordance with the Declaration of Helsinki and relevant institutional policies.

Measurements and Definitions

BMI was calculated as weight (kg) divided by height squared (m^2). Participants were categorized using World Health Organization (WHO) Asian-Pacific criteria: Normal (< 23 kg/m^2) and Overweight/Obese (≥ 23 kg/m^2) [9,10].

Body composition, including VFA and Skeletal Muscle Mass (SMM), was measured using a multi-frequency bioelectrical impedance analyzer (BIA) [11] (InBody 270; InBody Co., Ltd., Seoul, South Korea). Bioelectrical impedance analysis has shown acceptable agreement with imaging-based methods such as computed tomography for estimating visceral adiposity, although it is not a direct measurement [12,13]. VFA was categorized into two groups: Normal (< 100 cm^2) and High (≥ 100 cm^2), representing the established threshold for increased metabolic risk in Asian populations [14,15].

In order to avoid confounding by indication—where pharmacological treatment

masks underlying metabolic dysfunction—cardiometabolic abnormality was defined as the presence of at least one of the following laboratory thresholds or the current use of relevant medications, consistent with harmonized metabolic syndrome criteria [16,17]:
Blood pressure ≥ 130/85 mmHg or use of antihypertensive medication; Triglycerides ≥ 150 mg/dL or use of lipid-lowering medication; HDL cholesterol < 40 mg/dL (men) or < 50 mg/dL (women); HbA1c ≥ 5.7%, or use of antidiabetic medication.

The interval between BIA and laboratory measurements ranged from −57 to +60 days (median −7 days, interquartile range −26 to +12). To assess the impact of this variability, a sensitivity analysis restricted to a ±30-day window was performed. The persistence of a clear risk gradient (81.5% vs. 44.8%) indicates that temporal variation did not materially influence the observed associations, supporting the internal validity of the findings despite non-simultaneous measurements.

Statistical Analysis

Analyses were performed using Jamovi (Version 2.6). Continuous variables are presented as means ± standard deviations, and categorical variables as frequencies and percentages. Differences between categorical groups were assessed using Chi-square tests. Binomial logistic regression models, adjusted for age and sex, were used to evaluate the comparative associations of BMI and VFA with cardiometabolic abnormality [18]. A p-value of < 0.05 was considered statistically significant

RESULTS

Participant Characteristics

A total of 108 workers were included in the analysis (Table 1). The mean age of participants was 39.0 ± 8.4 years, with the majority being male (93.5%). The average body mass index was 26.3 ± 4.4 kg/m², indicating that most participants were within the overweight category based on Asian-Pacific criteria. Mean skeletal muscle mass was 29.9 ± 4.9 kg. A proportion of workers (15.7%) were receiving cardiometabolic-related medications. Overall, 63.0% of participants were classified as having at least one cardiometabolic abnormality.

Table 1. Participant Characteristics (N = 108)

Variable	Value
Age (years), mean ± SD	39.0 ± 8.4
Male sex, n (%)	101 (93.5%)
Body mass index (kg/m²), mean ± SD	26.3 ± 4.4
Skeletal muscle mass (kg), mean ± SD	29.9 ± 4.9
Any cardiometabolic medication, n (%)	17 (15.7%)
Cardiometabolic abnormality, n (%)	68 (63.0%)

Prevalence of Cardiometabolic Abnormalities

Overall, workers with a high VFA demonstrated a significantly greater prevalence of cardiometabolic abnormalities compared to those with a normal VFA. When stratifying the cohort by BMI, substantial disparities emerged based on visceral adiposity (Table 2).

Table 2. Cardiometabolic Risk Stratification by BMI-VFA Discordance.

BMI Category (Asian Cutoff)	Visceral Fat Area (VFA)	Total (N)	Abnormal n (%)	p-value*
Normal (<23 kg/m²)	Normal (<100 cm²)	22	12 (54.5%)	—
	High (≥100 cm²)	1	1 (100.0%)	—
Overweight/Obese (≥23 kg/m²)	Normal (<100 cm²)	45	22 (48.9%)	<0.001
	High (≥100 cm²)	40	33 (82.5%)	

* p-value derived from chi-square comparison within the Overweight/Obese subgroup.

Among the 85 workers classified as overweight or obese, 45 individuals maintained a normal VFA. The prevalence of abnormalities in the High BMI / High VFA group was 82.5%. In stark contrast, the High BMI / Normal VFA group exhibited a significantly lower abnormality prevalence of 48.9% ($p < 0.001$). Normal-weight central obesity was rare in this cohort (n = 1).

Regression and Sensitivity Analysis

In multivariable analysis (Table 3), high VFA was strongly associated with increased odds of cardiometabolic abnormality (OR: 6.66, 95% CI: 2.30–19.31, $p < 0.001$). Conversely, elevated BMI did not show an independent association after adjustment (OR: 0.50, 95% CI: 0.17–1.50, p = 0.219). The sensitivity analysis restricted to participants within a ± 30-day interval (n = 70) yielded highly consistent findings, with abnormality prevalence remaining distinctly stratified within the elevated BMI category (81.5% High VFA vs. 44.8% Normal VFA). Although skeletal muscle mass increased with BMI and VFA, it did not meaningfully alter the association between visceral adiposity and cardiometabolic abnormality.

Predictor	Adjusted OR	95% CI	p-value
Visceral fat area (high vs. normal)	6.66	2.30 – 19.31	<0.001
Age (per year increase)	1.07	1.01 – 1.14	0.026
BMI category (≥23 vs. <23 kg/m²)	0.50	0.17 – 1.50	0.219
Sex (male vs. female)	1.07	0.18 – 6.49	0.943

DISCUSSION

This study demonstrates that visceral fat area provides essential, additional cardiometabolic risk stratification beyond body mass index in an industrial workforce [19]. While BMI remains a practical baseline screening tool, our findings indicate that it lacks the specificity required to accurately assess metabolic risk in this population, likely due to variations in body composition [3].

A key finding is the marked difference in metabolic risk within the overweight/obese BMI category. Over half of the workers flagged as high-risk by BMI maintained normal visceral adiposity and consequently presented with substantially lower rates of cardiometabolic abnormalities (48.9% vs. 82.5%). Fat distribution appears to be more closely related to metabolic risk than overall body size. In multivariable analysis, visceral adiposity emerged as the dominant predictor of metabolic risk, substantially reducing the independent predictive value of BMI [20]. Although BMI was not independently associated with cardiometabolic abnormality after adjustment, the direction of the effect (OR < 1.0) is noteworthy. Given the collinearity between BMI and visceral fat area, the inclusion of VFA in the model isolates the residual variance of BMI, which likely reflects fat-free mass and peripheral (non-

visceral) adiposity. In this context, the inverse association suggests that, at a given level of visceral adiposity, greater overall body mass may represent higher skeletal muscle content, which is metabolically protective. This interpretation is consistent with evidence linking lean mass to improved insulin sensitivity and cardiometabolic profiles.

Consistent with this interpretation, although skeletal muscle mass increased with BMI, it did not explain the differences in cardiometabolic risk. Workers with similar overall body sizes but higher visceral adiposity exhibited substantially greater metabolic abnormalities. This indicates that the anatomical distribution of fat is far more relevant to metabolic health than total body mass or absolute muscle mass [21, 22]. These findings support the physiological concept that visceral adiposity is strongly implicated in metabolic dysfunction, including insulin resistance and pro-inflammatory states [23, 24].

The consistency of findings in the ±30-day sensitivity analysis further supports the robustness of the observed associations, indicating that temporal variation between body composition and laboratory measurements did not materially influence the results.

In active occupational settings, reliance on BMI alone may lead to misclassification of metabolic risk in individuals with varying body composition [2]. Incorporating VFA into PME can prevent this misclassification, allowing occupational health practitioners to target interventions toward workers with true metabolic derangement.

Limitations

This study is subject to several limitations. Its cross-sectional design precludes causal inference. Body composition was assessed using bioelectrical impedance analysis, which may be influenced by hydration status. Although the interval between BIA and laboratory measurements varied, the ±30-day sensitivity analysis confirmed that temporal differences did not materially affect the observed associations. The use of a composite binary outcome for cardiometabolic abnormality, while consistent with harmonized metabolic syndrome criteria, may obscure differential effects of visceral adiposity across individual metabolic pathways. By prioritizing overall risk detection, this approach limits mechanistic specificity, and future studies examining individual components may provide further insight. The cohort was predominantly male (93.5%), reflecting the industrial workforce but potentially limiting generalizability to female populations.

These findings should therefore be interpreted within the context of occupational health surveillance, where the primary objective is risk stratification for fitness-for-work decision making rather than detailed pathophysiological characterization.

CONCLUSION

Visceral fat area significantly improves cardiometabolic risk stratification beyond body mass index. In an industrial workforce, fat distribution, rather than overall body size, is the strongest associated factor of cardiometabolic risk. Integrating VFA into routine occupational health surveillance enhances precise identification of at-risk individuals and reduces the misclassification inherent in BMI screening.
In this context, VFA-informed assessment provides a more actionable basis for fitness-for-work decision making, enabling targeted intervention toward workers with true

metabolic risk while avoiding unnecessary restriction in those with elevated BMI but low visceral adiposity

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