



EVALUATING THE EFFICACY OF VISCERAL ADIPOSITY INDEX (VAI) AS A PREDICTOR OF CARDIOMETABOLIC RISK FACTORS: A COMPARATIVE COMMUNITY-BASED STUDY AMONG INDUSTRIAL WORKERS IN WEST BENGAL AND GUJARAT

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Abstract

Background: Industrial workers in India face a heightened risk of cardiometabolic diseases due to sedentary occupational stress and rapid lifestyle transitions. While Body Mass Index (BMI) is widely used, it often misses "metabolically obese" individuals. This study evaluates the efficacy of the **Visceral Adiposity Index (VAI)**—a mathematical model integrating anthropometric and biochemical parameters—as a predictor of cardiometabolic risk factors among industrial cohorts in West Bengal and Gujarat.

Methods: A comparative community-based cross-sectional study was conducted involving **600 industrial workers** (300 from Durgapur, West Bengal, and 300 from Ahmedabad, Gujarat). Physiological assessments included blood pressure, waist circumference, and BMI. Biochemical analysis for fasting blood glucose and lipid profiles (TG and HDL) was performed to calculate the VAI. Cardiometabolic risk was defined by the presence of hypertension, dyslipidemia, or impaired fasting glucose.

Results: The mean VAI was significantly higher in the Ahmedabad cohort (4.1 ± 1.2) compared to the Durgapur cohort (3.6 ± 1.4 , $p < 0.05$). Across both regions, VAI showed a stronger positive correlation with systolic blood pressure ($r = 0.58$) and fasting glucose ($r = 0.62$) than BMI ($r = 0.34$). Receiver Operating Characteristic (ROC) analysis revealed that VAI had a superior Area Under the Curve (AUC = 0.86) for predicting metabolic syndrome compared to waist circumference alone (AUC = 0.72).

Conclusion: VAI is a more potent and gender-specific indicator of cardiometabolic risk than traditional anthropometric measures in Indian industrial workers. Incorporating VAI into routine occupational health screenings can facilitate earlier identification of high-risk individuals, allowing for targeted primary prevention in these vital economic hubs.

Keywords: Visceral Adiposity Index, Cardiometabolic Risk, Industrial Workers, Durgapur, Ahmedabad, Metabolic Syndrome.

Introduction

The global landscape of public health is currently witnessing a seismic shift from infectious diseases to non-communicable diseases (NCDs), with cardiovascular diseases (CVDs) and metabolic disorders leading the mortality charts. In the rapidly developing economy of India, this transition is particularly pronounced among the urban workforce. Industrial hubs like **Durgapur (West Bengal)** and **Ahmedabad (Gujarat)** serve as the backbone of the nation's manufacturing and steel sectors, yet the populations driving these industries are increasingly vulnerable to a cluster of physiological abnormalities known as **Metabolic Syndrome (MetS)**. This study focuses on the **Visceral Adiposity Index (VAI)** as a superior physiological marker for identifying cardiometabolic risk in these high-stress industrial environments.

1. The Industrial Health Paradox in India

India's industrial workers represent a unique demographic. While their labor drives national GDP, the "industrial lifestyle" often involves a combination of high-calorie, high-carbohydrate diets, irregular shift patterns, and high levels of environmental and psychological stress. In cities like Durgapur, the heavy engineering and steel industries dominate, while Ahmedabad is a global center for textiles and chemicals. Despite the geographical and cultural distance between West Bengal and Gujarat, the workers in both regions share a common risk: the **"Asian Indian Phenotype."** This phenotype is characterized by a "thin-fat" body composition—individuals who may appear to have a normal weight according to Western standards but possess high levels of internal body fat, low muscle mass, and profound insulin resistance. Traditional public health metrics, primarily the **Body Mass Index (BMI)**, often fail to capture this risk. A worker in a Durgapur steel plant may have a BMI of 23 kg/m^2 (classified as normal) but may simultaneously suffer from significant visceral fat accumulation, placing them at an invisible but high risk for sudden cardiac events.

2. Beyond BMI: The Physiology of Visceral Fat

For decades, BMI has been the primary tool for obesity screening due to its non-invasive nature. However, from a **Physiological** standpoint, BMI is flawed because it does not distinguish between bone, muscle, and fat, nor does it identify where fat is stored. Research has conclusively shown that **subcutaneous fat** (fat under the skin) and **visceral fat** (fat surrounding the internal organs) have vastly different metabolic impacts.

Visceral adipose tissue (VAT) is not merely a storage depot for energy; it is a highly active endocrine and inflammatory organ. It secretes an array of pro-inflammatory cytokines, such as **Interleukin-6 (IL-6)** and **Tumor Necrosis Factor-alpha (TNF- α)**, while reducing the secretion of the cardioprotective hormone **Adiponectin**. Furthermore, visceral fat has a high rate of lipolysis, releasing free fatty acids (FFAs) directly into the portal circulation. This "portal flux" of fatty acids to the liver promotes hepatic insulin resistance and stimulates the production of triglyceride-rich lipoproteins, creating a pro-atherogenic environment.

3. The Visceral Adiposity Index (VAI) as a Diagnostic Evolution

To address the limitations of BMI and simple waist circumference (WC), the **Visceral Adiposity Index (VAI)** was developed. VAI is a gender-specific mathematical model that incorporates both anthropometric data (BMI and WC) and biochemical markers (Triglycerides and HDL-C). By combining structural measurements with functional lipid markers, the VAI provides a holistic "score" of adipose tissue dysfunction. The physiological rationale for VAI is grounded in its ability to reflect "adipose tissue sickness." While WC tells us about the *quantity* of abdominal fat, the inclusion of Triglycerides (TG) and High-Density Lipoprotein (HDL) in the VAI formula tells us about the *quality*

and *metabolic activity* of that fat. In a community setting, where expensive imaging like MRI or CT scans to measure visceral fat is impossible, the VAI offers a "poor man's gold standard" for cardiometabolic assessment.

4. Community Medicine and Occupational Risk

From a **Community Medicine** perspective, the industrial workforce in India is a "captured population" that is often overlooked until clinical disease manifests. In Ahmedabad and Durgapur, occupational health screenings are frequently limited to basic height, weight, and perhaps blood pressure. There is a critical gap in preventative screening that can identify the "pre-metabolic" state. The transition from a rural, physically active lifestyle to an urban, industrial, and sedentary one is a primary driver of the NCD epidemic. Industrial workers often face:

- **Circadian Disruption:** Shift work interferes with glucose metabolism and lipid regulation.
- **Psychosocial Stress:** High production targets in industrial settings increase cortisol levels, which specifically promotes visceral fat deposition.
- **Dietary Shifts:** Increased consumption of processed foods high in trans-fats and refined sugars, common in urban industrial canteens.

Materials and Methods

1. Study Design and Participants

A community-based, cross-sectional, comparative study was conducted between January 2023 and October 2023. The study population consisted of full-time industrial workers from two major economic zones in India:

- **Group A (East):** Workers from iron and steel manufacturing units in **Durgapur, West Bengal**.
- **Group B (West):** Workers from textile and chemical industries in **Ahmedabad, Gujarat**.

Sample Size: A total of **600 participants** (300 from each region) were recruited using a multi-stage random sampling technique.

Inclusion Criteria:

- Age group: 25–55 years.
- Minimum of 2 years of continuous employment in the respective industry.
- Willingness to provide informed consent.

Exclusion Criteria:

- Pre-existing chronic kidney or end-stage liver disease.
- Known cases of Type 1 Diabetes or those on insulin therapy.
- History of heavy alcohol consumption (to avoid confounding of hepatic fat).
- Use of systemic steroids or lipid-lowering drugs (Statins/Fibrates).

2. Ethical Considerations

The study protocol was approved by the Institutional Ethics Committees of **IQ-City Medical College** and **SAL Institute of Medical Sciences**. All participants were informed about the nature of the study in their local languages (Bengali/Gujarati/Hindi), and written informed consent was obtained.

3. Data Collection and Anthropometry

Data collection was performed during morning shifts to ensure standardized physiological conditions.

- **Physical Examination:** Height was measured to the nearest 0.1 cm using a stadiometer. Weight was measured using a calibrated digital scale. **Body Mass Index (BMI)** was calculated as $\text{Weight(kg)/height(m}^2\text{)}$.
- **Waist Circumference (WC):** Measured at the midpoint between the lower rib and the iliac crest using a non-stretchable tape at the end of a normal expiration.

- **Blood Pressure (BP):** After 15 minutes of rest, two readings were taken using a mercury sphygmomanometer in the sitting position, and the average was recorded.

Results

A total of **600 participants** (300 from Durgapur, West Bengal and 300 from Ahmedabad, Gujarat) were analyzed. The demographic was predominantly male (82%), reflecting the industrial workforce composition, with a mean age of **38.4 ± 7.2 years**

1. Regional Comparison of Physiological & Biochemical Profiles

The comparative analysis between the Eastern (Durgapur) and Western (Ahmedabad) cohorts revealed significant regional variations in metabolic health.

Parameter	Durgapur (n=300)	Ahmedabad (n=300)	p-value
Mean BMI (kg/m ²)	24.2 ± 3.1	25.8 ± 3.5	<0.05
Waist Circumference (cm)	88.4 ± 6.2	92.1 ± 7.4	<0.01
Systolic BP (mmHg)	126 ± 12	132 ± 14	<0.01
Triglycerides (mg/dL)	142 ± 28	168 ± 35	<0.001
HDL Cholesterol (mg/dL)	44 ± 6	39 ± 5	<0.01
Mean VAI Score	3.6 ± 1.4	4.1 ± 1.2	<0.05

Observation: The Ahmedabad cohort exhibited significantly higher VAI scores and triglyceride levels compared to the Durgapur cohort, likely reflecting regional dietary differences and higher sedentary stress in the chemical/textile sectors.

2. Prevalence of Cardiometabolic Risk Factors

The prevalence of key risk factors across the entire industrial population (N=600) was high:

- **Hypertension ($\geq 140/90$ mmHg): 28.5%**
- **Hypertriglyceridemia (≥ 150 mg/dL): 41.2%**
- **Low HDL-C: 48.6%**
- ****Impaired Fasting Glucose**

Discussion

The results of this comparative study between industrial workers in **Durgapur (West Bengal)** and **Ahmedabad (Gujarat)** underscore a critical transition in occupational health. The core finding—that the **Visceral Adiposity Index (VAI)** serves as a more potent predictor of cardiometabolic risk than traditional metrics like BMI—has profound implications for how we screen and manage the health of the Indian workforce.

1. The "Thin-Fat" Phenotype in the Industrial Workforce

A striking observation in our results was the prevalence of cardiometabolic risk factors even among workers with a "normal" BMI (<23 kg/m² by Asian standards). In the Durgapur cohort, nearly **22%** of participants categorized as non-obese by BMI exhibited high VAI scores and hypertension. This confirms the existence of the "metabolically obese, normal-weight" (MONW) phenotype in the Indian industrial sector. Physiologically, this is explained by the preferential deposition of fat in the visceral compartment rather than the subcutaneous layer. Unlike subcutaneous fat, which acts as a passive energy reservoir, visceral fat is a chemically active "gland" that releases inflammatory cytokines directly into the portal vein. The VAI, by incorporating Triglycerides and HDL, effectively captures the "sick" nature of this adipose tissue, whereas BMI merely measures total mass.

2. Regional Disparity: West Bengal vs. Gujarat

The significantly higher mean VAI (4.1 $\pm$ 1.2) and triglyceride levels in the **Ahmedabad** cohort compared to **Durgapur** (3.6 $\pm$ 1.4) suggests that regional lifestyle factors play a major role in metabolic health.

- **Dietary Influence:** The traditional diet in Gujarat often includes higher levels of refined sugars and fats (e.g., vanaspati), which are direct precursors to hypertriglyceridemia. In contrast, the West Bengal diet, while high in carbohydrates (rice), often includes mustard oil and fish, which may offer a slightly different lipid profile, though still high in glycemic load.
- **Occupational Nature:** The chemical and textile industries in Ahmedabad often involve high-temperature environments and localized sedentary monitoring, whereas the steel and heavy engineering sectors in Durgapur may involve more intermittent physical exertion.

Despite these differences, the **correlation** between VAI and cardiometabolic risk remained high in both groups, proving that VAI is a globally applicable tool across diverse Indian sub-populations.

3. VAI as a Multi-Systemic Marker

Our correlation analysis showed that VAI was more closely linked to **Systolic Blood Pressure** ($r = 0.58$) and **Fasting Glucose** ($r = 0.62$) than Waist Circumference alone. This suggests that VAI is not just a marker of "fatness," but a marker of **insulin resistance**. High VAI reflects an increase in free fatty acids (FFAs) which interfere with insulin signaling in the muscle and liver. This leads to compensatory hyperinsulinemia, which in turn stimulates the sympathetic nervous system and increases sodium reabsorption in the kidneys, ultimately manifesting as hypertension. By the time a worker presents with high blood pressure in a community clinic in Ahmedabad or Durgapur, the underlying visceral dysfunction (captured by VAI) has likely been present for years.

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