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Introduction

Body fat distribution is an essential risk factor for cardiometabolic outcomes among the general population. An individual's surplus body fat with a predominant android than gynoid will have adverse health effects. Due to the presence of visceral fat, the onset of metabolic disturbances is caused differently for every obese individual depending upon the amount of fat distributed in the abdominal region. The onset of complications is associated with obesity phenotype and metabolic dysfunction by cells inflation by fat distribution. As a result, clinical detection of fat has become increasingly important.

The fat or adipose tissue is a conjugative loose tissue mainly comprised of adipocytes which play a vital role in energy storage in lipids. The fat tissue serves as a principal cushion by insulating the body. The distribution and the amount of fatty tissue present all over the body are influenced by numerous clinical, psycho-social and physiological factors. The beneath-skin fat layer is called subcutaneous adipose tissue (SAT); the integral organs' fat lining is visceral adipose tissue (VAT). The distribution of the two adipose tissue within the body has considerable anatomical differences (Mittal, 2019).

Several health risks are associated with high amounts of total body fat (TBF), visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT), including insulin resistance, hepatic steatosis, metabolic syndrome and hypertension. Epidemiological studies highlighted that VAT accumulation is associated with increased metabolic risk and overall mortality, whereas SAT expansion ameliorates insulin sensitivity and decreases the risk of type 2 diabetes (T2D).

The risks are affected by genetic, biological and lifestyle factors including physical activity, nutrition and stress. The chief determinant of insulin resistance is visceral fat. Many investigators have established links between excessive visceral fat and an exaggerated inflammatory state (Frayn, 2000). A close relationship

exists between high morbidity and intra-abdominal (visceral) fat obesity, rather than extra-abdominal (subcutaneous) fat obesity.

Visceral fat is particularly deleterious because of its anatomical location and the increased supply of free fatty acids to the liver (Ebbert & Jensen, 2013). The adipose tissue present can enlarge to severity levels. Visceral adiposity is considered a preeminent component for the onset of metabolic disturbances in the body (Neeland et al., 2013). The visceral fat accumulates in three places: (i) subcutaneous fat, (ii) retro-peritoneal fat, and (iii) visceral fat (Hsieh et al., 2014). Nevertheless, visceral fat is considered the most atherogenic, diabetogenic and hypertensiogenic fat depot.

The visceral adiposity in specific is the high amount of fat distributed in the abdominal region. Even though the cause for mortality is obesity, it is visceral adiposity, an active organ, and a potent risk factor associated with metabolic derangements compared to general obesity (Arimura et al., 2011).

The worldwide prevalence of visceral adiposity was found to be 41.5%. Additionally, from 1985-1999 to 2010-2014, an extreme increase was seen between the younger age group (15-35 years) of 16.3% to 33.9% compared to the older age group (Wong et al., 2020). The Indian prevalence of visceral adiposity was higher than the generalized obesity and in Tamil Nadu was 26.6%, specifically higher among the urban population of 37.4%. It was also noted that women had a higher prevalence rate of 32.2% than men (Pradeepa et al., 2015).

Moreover, Asian Indians have a greater risk for metabolic syndrome (Mets), diabetes mellitus and coronary artery diseases (Prasad et al., 2012). As a potent risk factor among Asian Indians, the fat accumulated can be identified even at lower body mass index as central obesity which is termed as “Asian Indian phenotype” that give rise to higher levels of triglyceride and lower levels of high-density lipoprotein resulting in metabolic dysfunction (Singh et al., 2014). They possess a relatively higher percentage of fat accumulation in the abdominal region with lower fat-free mass, thereby inducing insulin resistance, which occurs at lower BMI (Misra, 2015), resulting in metabolic abnormalities. Individuals with normal weight with lower BMI might have a higher risk of causing metabolic

dysfunction (Sahakyan et al., 2015). The onset of metabolic dysfunction among normal-weight individuals ascribes to dysfunction of peripheral fat tissue because of irregular penetration of macrophages or monocytes, but the visceral adiposity is not affected (Indias et al., 2016).

The visceral adipose tissue is a metabolically active organ and intra-abdominal obesity is an independent risk factor for the metabolic alterations associated with the development of cardiovascular diseases (CVD) and type II diabetes mellitus in adults (Chait & Hartigh, 2020). Adipose tissue dysfunction and dyslipidemia are not necessarily associated with obesity; they can occur in a minor increase in body weight even among non-obese (Chandalia et al., 2012)

The Visceral Adiposity Index (VAI) and Lipid Accumulation Product (LAP) are becoming novel health assessment indexes and potent markers to stratify adults for obesity phenotypes (Du et al., 2015). VAI is a gender-specific calculative index, which includes the anthropometric measurements and biochemical parameters, which have shown to be related to adipose tissue dysfunction and express visceral fat distribution (Amato et al., 2010). VAI can aid in evaluating the manifestation and is considered a surrogate marker of visceral adipose tissue dysfunction (Nayak et al., 2020; Kumpatla et al., 2011). It reflects the severity of insulin resistance and exhibits a strong association with both glucose utilization and the MRI's visceral adipose tissue.

A novel sex-specific index like VAI is highly correlated with visceral adiposity measured by the standard gold method magnetic resonance imaging and also showed correlation with significance between VAI and bioelectric impedance (BIA) measured visceral adipose tissue (VAT) (Lietz et al., 2017). Hence, VAI can be a proxy marker of VAT (Liu et al., 2016). VAI is supposed to provide a standby marker of functional, structural adiposity and visceral adipose dysfunction (Bozorgmanesh et al., 2011). It is also determined to represent a global calculator of non-glycemic and non-hemodynamic components of metabolic syndrome and includes variables like gender and BMI. Visceral fat accumulates as age progresses depending on gender (Canepa et al., 2013).

As the lipid accumulates and increases in the visceral fat tissue, the concentration of specific blood will elevate, which is termed “lipid over accumulation.” The accumulated lipid is measured explicitly by leading to physiological danger by lipid accumulation product (Unger, 2003). Lipid accumulation product index (LAP), a recently developed empirical biomarker for central accumulation of fat and indicates the risk of insulin resistance, metabolic syndrome, type 2 diabetes, and cardiovascular disease (Mirmiran et al., 2014; Wakabayashi et al., 2014; Ferreira et al., 2017). LAP reflects both the anatomic and physiological changes associated with lipid over accumulation.

The LAP is also a good marker of lipid accumulation in the ectopic deposition of fat tissue in the non-adipose layer (Dev, 2016). This ectopic deposition of fat leads to metabolic injury (Egziabher et al., 2013). Overall, the dysfunction of adipose tissue, release of adipokines and the ectopic deposition of lipids will impair tissue insulin sensitivity leading to toxicity of lipids thereby causing altered glucose metabolism (Nusrianto et al., 2019). The higher LAP has been associated with abnormal glucose homeostasis and insulin resistance (Oh et al., 2013). Among the young adult population, particularly women, LAP is used as a marker for detecting metabolic abnormalities at an earlier stage (Brisson et al., 2010).

Even though a link between obesity and metabolic dysfunction is seen, visceral adiposity is the main evolving culprit (Morttillo et al., 2010). However, not all obese individuals have metabolic dysfunction stating that 10 to 25% of obese individuals are metabolically healthy (MHO) (Pajunen et al., 2011; Goncalves et al., 2016) contrary even normal-weight individuals are metabolically unhealthy (MUNW). Visceral Adiposity Index and Lipid Accumulation Product can indirectly reflect insulin resistance by the amount of visceral fat tissue present. The important reason for this is fat accumulation and insulin sensitivity (Nascimento et al., 2015).

Most obese individuals have insulin resistance termed hyperinsulinemia, the initial step of metabolic dysfunction (Paniagua, 2016). Nevertheless, among the obese, the adverse reactions are absent for some individuals termed as

metabolically healthy obese. One of the criteria and factors around the metabolically healthy obese is insulin resistance. The contributing mechanism of metabolic syndrome is insulin resistance like dysfunction in visceral fat tissue, oxidative stress, chronic inflammation, disruption in circadian and microbiota, genetic and maternal factors (Xu et al., 2018).

Insulin-dependent tissues become less sensitive to the actions of insulin in insulin resistance leading to an imbalance in metabolism (Paneni et al., 2014). Several risk factors (eg. obesity, physical inactivity, body fat distribution and age) may be considered markers of insulin resistance. Insulin resistance is a predictor for Type 2 diabetes mellitus even in individuals with normal glucose tolerance (Bray, 2004). Therefore, it is important to recognize insulin resistance in the pre-disease stage when therapeutic intervention is more successful than manifesting diseases.

A higher rate of lipolysis and pro-inflammatory secretion of adipokines will lead to low-level inflammation, which modifies insulin's signal in visceral adipose tissue (Verboven et al., 2018). However, the visceral adiposity cell tissues have a greater lipid breakdown (lipolysis) rate, producing adipocytokines, namely plasminogen activator inhibitor-1 and interleukin-6 (Freedland, 2004). Visceral adiposity has been prolonged associated with insulin resistance and increased cardiovascular risk. The individuals with risk can be identified directly by measuring insulin resistance associated with developing metabolic disturbances and other lifestyle diseases (Salazar et al., 2021).

Insulin resistance can be determined easily through HOMA-IR (Homeostasis Model Assessment of Insulin Resistance), which can be frequently used in clinical practice more economically although quite expensive in primary care. HOMA-IR defines insulin resistance as an effective substitute for ethical, cost-effective and feasible. It is highly correlated with the standard methods of assessing insulin resistance by glucose clamp techniques (Wallace et al., 2004). The Homeostasis Model Assessment of Insulin Resistance measures fasting serum glucose (FBS) and fasting insulin (FI). The advantage of HOMA-IR in assessing insulin resistance is that it’s been validated among the different age

groups. The analysis estimates the β- cell function and insulin resistance, distinguishing the physiological path with impaired glucose tolerance. Studies among normal individuals who can develop irregular glucose tolerance are useful across ethnic groups. The limitation of HOMA-IR is that it cannot be used among patients with insulin treatment (Bhosle et al., 2016).

Numerous experimental and epidemiological studies suggest that the anatomic adipose fat tissue layer is needed for life expectancy, health and the development of diseases as visceral adiposity plays a crucial risk factor (Global BMI Mortality Collaboration, 2016). Overall, multiple studies and several guidelines emphasize that early intervention among Asian ethnic groups is essential for preventing and managing obesity-related non-communicable diseases.

In women, adiposity in middle age is substantially linked to a lower likelihood of long-term healthy survival. There is no doubt that the first-line treatment of obesity is dietary management combined with behavior modification and increased physical activity (Mozaffarian et al., 2011). Intervention programs, specifically early-stage intervention are related to performance among a specified population providing a therapeutic or preventive regimen to overcome the onset of further diseases/ disorders. The early intervention requires an iterative process to identify effective strategies for promoting behavioral change and positive effects at the community level. The appropriate intervention is essential in the community-based study to determine the program's effectiveness and forward the research to the community.

The rationale for the study

The novel VAI and LAP can be viable health assessment indexes because they are less invasive and used in community-level screening. The VAI and LAP standards are not available since it is ethnic-specific. The visceral adiposity present among populations differs widely, as it is more common among South Asians (Misra & Shrivastava, 2013). Identifying high-risk individuals among obese and non-obese is essential, importantly non-obese who are metabolically unhealthy.

In this perspective, Indian studies are minimal and hence validating and deriving the cut-off value of visceral adiposity indices is essential among the Indian women population, which can bring in many interesting findings concerning insulin resistance to reduce the risk factors in women's health. This study will be the first in deriving the cut-off value of visceral adiposity indices among general adult women. Since women have high peripheral subcutaneous fat distribution in early young adulthood and as age progresses, there is a uniform increase in deposition and distribution of visceral fat.

Identifying women at risk, such as those with insulin resistance syndrome, would provide an opportunity for possible prevention. Evidence-based studies to find out the association of visceral adiposity and insulin resistance and promote intervention strategies to reduce VAI and LAP are the need of the hour so that primary prevention of obesity can be achieved. Thus, the present study was executed with primary and secondary objectives.

Objectives of the study:

Primary Objectives:

To

- Find the prevalence of obesity among adult women.
- Associate and correlate visceral adiposity index, lipid accumulation product and insulin resistance among experimental and control groups.
- Find the risk factors and cut-off points associated with Visceral Adiposity Index and Lipid Accumulation Product

Secondary Objectives:

- Apply and validate visceral adiposity index and lipid accumulation cut-off points among adult women
- Study the dietary pattern among experimental and control groups.
- Assess the physical activity pattern among experimental and control groups.
- Study the anthropogens among experimental and control groups.

- Impart intervention for obesity management and evaluate the impact of the intervention on VAI and LAP.

Hypothesis

Hypotheses framed for the present study were:

- **Hypothesis 1**

H_0 = No association between VAI, LAP and insulin resistance.

H_1 = There is a positive association between VAI and LAP and insulin resistance.

- **Hypothesis 2**

H_0 = There is no association of Diet and Physical activity intervention in reducing visceral adiposity.

H_1 = There is a positive association between Diet and Physical activity intervention in reducing visceral adiposity.