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THE LIPID ACCUMULATION PRODUCT INDEX AS AN ALTERNATIVE BIOMARKER FOR EARLY DETECTION OF METABOLIC SYNDROME: A NARRATIVE REVIEW

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ABSTRACT

Background: Metabolic syndrome (MetS) is a cluster of metabolic disorders that increases the risk of cardiovascular disease and type 2 diabetes. Early detection is crucial, especially in developing countries with limited healthcare services and infrastructure. The lipid accumulation product (LAP) index offers a simple, affordable, and accurate alternative biomarker because it reflects visceral fat accumulation as a significant risk factor for MetS.
Objective: This review aims to evaluate the potential of the LAP index as an alternative biomarker for MetS screening through a narrative review of various global epidemiological studies.
Methods: This study employs a narrative review approach, incorporating theoretical analysis and data from international articles. The search was conducted across several databases, including PubMed, ScienceDirect, and Google Scholar. Data were searched from peer-reviewed articles published between 2016 and 2025 using several selected keywords, including lipid accumulation product, metabolic syndrome, biomarkers, visceral fat, and insulin resistance.
Results: A review of 10 studies showed that the LAP index had an area under the curve (AUC) value > 0.850 in most studies, with sensitivity (Sn) and specificity (Sp) generally exceeding 80%. The LAP index also demonstrated better or comparable diagnostic performance to other biomarkers. In addition to its good statistical validity, this index also excels in terms of physiology and practicality.
Conclusion: The LAP index has the potential to serve as an efficient, affordable, and applicable biomarker for screening MetS based on various global epidemiological studies, and supports more targeted prevention and lifestyle interventions in at-risk individuals.

Keywords: Lipid accumulation product; metabolic syndrome; biomarker; visceral fat; insulin resistance

INTRODUCTION

Metabolic syndrome (MetS) is a multifactorial condition characterised by the presence of several metabolic disorders, such as central obesity, dyslipidemia, hypertension, and insulin resistance (IR).[1,2] MetS is known to contribute to an increased risk of cardiovascular disease (CVD), stroke, and type 2 diabetes mellitus (T2DM), and is one of the main factors driving high morbidity and mortality rates globally.[3,4]

Globally, the prevalence of MetS is estimated to range from 12.5% to 31.4%, and shows a consistent upward trend across all age groups and genders.[5,6] The prevalence of MetS in the Asia-Pacific, especially in developing countries, shows an alarming epidemiological situation with rates ranging from 12% to 37%.[7] In Indonesia, the prevalence of Metabolic Syndrome (MetS) reaches 21.66%[8] The incidence rate among women (46%) is twice as high as that among men (28%).[9]

The trend of increasing MetS is related to a shift towards unhealthy eating patterns, decreased physical activity, increasingly sedentary lifestyles, and high prevalence of obesity. In Indonesia alone, the prevalence of obesity has also continued to increase by 8.6% over the past decade.[10–12] Given the long-term consequences of MetS on health, early detection efforts are crucial for preventing chronic diseases and reducing the burden on public health.[13]

Various international organizations have proposed diagnostic criteria for MetS, including the most recent Harmonizing the Metabolic Syndrome: A Joint Interim Statement (JIS) in 2009.[14–17] Although commonly used, these criteria still rely on complex indicators and are not yet ideal for use in large-scale screening, especially in developing countries with limited primary health services and infrastructure. Additionally, their inability to accurately represent the distribution of visceral fat, a key factor in the transition from insulin resistance (IR) to the development of metabolic syndrome (MetS), is a particular concern.[18] Therefore, alternative biomarkers are needed that are simpler, more practical, yet still accurate for early identification of MetS.

Considering the importance of fat mass and its distribution pattern in metabolic processes, several alternative biomarkers have been evaluated to enhance the accuracy of MetS diagnosis. One that stands out is the Lipid Accumulation Product Index (LAP), a simple, affordable, and more specific biomarker for evaluating visceral fat accumulation and metabolic disorders closely associated with insulin resistance, dyslipidemia, and activation of the renin-angiotensin-aldosterone system (RAAS).[19,20–26] This index is calculated based on a combination of two parameters that are routinely measured in clinical practice, namely waist circumference (WC) and triglyceride levels (TG). In addition, the validity of the LAP index has been tested in various cross-population epidemiological studies, yielding consistent results that demonstrate high accuracy in identifying MetS risk.[27–29]

However, although the global burden of MetS continues to rise, studies specifically evaluating the accuracy and applicability of the LAP index as a screening tool across diverse populations, particularly in low-income and developing countries, remain limited. This situation creates an important research gap, as most available evidence originates from high-income settings, while developing countries experience a disproportionately higher increase in MetS prevalence but have fewer resources to support complex diagnostic methods. In this context, there is a growing need for simple, low-cost, and easily applicable indicators that can support population-level MetS screening and early detection programs, rather than being restricted to individual risk assessment.

Therefore, examining global findings is essential not only to understand the universal relevance of the LAP index but also to evaluate its feasibility as a large-scale screening tool for populations with diverse metabolic, genetic, and lifestyle characteristics. Because the LAP index relies solely on WC and TG measurements, it has strong potential for implementation in public health surveillance and mass screening initiatives, particularly in countries with limited health infrastructure. Accordingly, this narrative review aims to evaluate the role of the LAP index as an alternative biomarker for the early detection of MetS by synthesizing global epidemiological evidence and discussing its potential applicability within developing-country contexts, such as Indonesia.

THEORETICAL FRAMEWORK

Definition of Metabolic Syndrome

MetS has been defined by various international organizations, including the most recent Harmonizing the Metabolic Syndrome: A Joint Interim Statement (JIS) in 2009.[14–17] In the latest criteria, several major organizations have agreed that there are no mandatory components among the five components of MetS, namely: (1) Central Obesity; (2) High TG: ≥ 150 mg/dL (1.7 mmol/L); (3) High Density Lipoprotein (HDL): HDL < 40 mg/dL (1.03 mmol/L) in men or < 50 mg/dL (1.29 mmol/L) in women; (4) High Blood Pressure: Systolic blood pressure ≥ 130 mmHg or diastolic ≥ 85 mmHg; (5) High Fasting Blood Glucose (FBG): Blood glucose ≥ 100 mg/dL (5.6 mmol/L). Three of the five abnormal findings from the MetS components will still qualify an individual for a MetS diagnosis. A single cutoff point will be used for all MetS components except waist circumference, which will be adjusted according to national or regional guidelines.[30]

Pathogenesis of Metabolic Syndrome

The pathophysiology of MetS involves complex mechanisms that are not yet fully understood, including debate over whether its components are independent or interrelated in a single pathogenic process. In addition to genetic and epigenetic factors,[31] unhealthy lifestyles, such as excessive calorie consumption and lack of physical activity, are the leading causes. Excess energy is stored as fat, particularly in metabolically active visceral tissue. This tissue releases free fatty acids (FFAs), pro-inflammatory cytokines, and adipokines that trigger IR, chronic inflammation, and hormonal dysfunction, which in turn disrupt glucose, lipid, and blood pressure metabolism—the three main components of MetS.[13] Several key mechanisms thought to be involved in the development of MetS and its transition to CVD and T2DM include IR, chronic inflammation, and activation of the neurohormonal system. IR causes impaired glucose uptake by muscles and adipose tissue, leading to hyperglycemia and compensatory hyperinsulinemia. Chronic inflammation originating from visceral adipose tissue increases the production of proinflammatory cytokines that interfere with insulin signalling pathways and exacerbate metabolic dysfunction. Meanwhile, activation of the neurohormonal system, particularly the sympathetic nervous system and the renin-angiotensin-aldosterone system (RAAS), leads to an increase in blood pressure and sodium retention, which contributes to hypertension, a key component of MetS. A summary of the proposed pathophysiological mechanism of Metabolic Syndrome, including the roles of visceral adiposity, chronic inflammation, hormonal activation, and insulin resistance, is presented in Figure 1.[32]

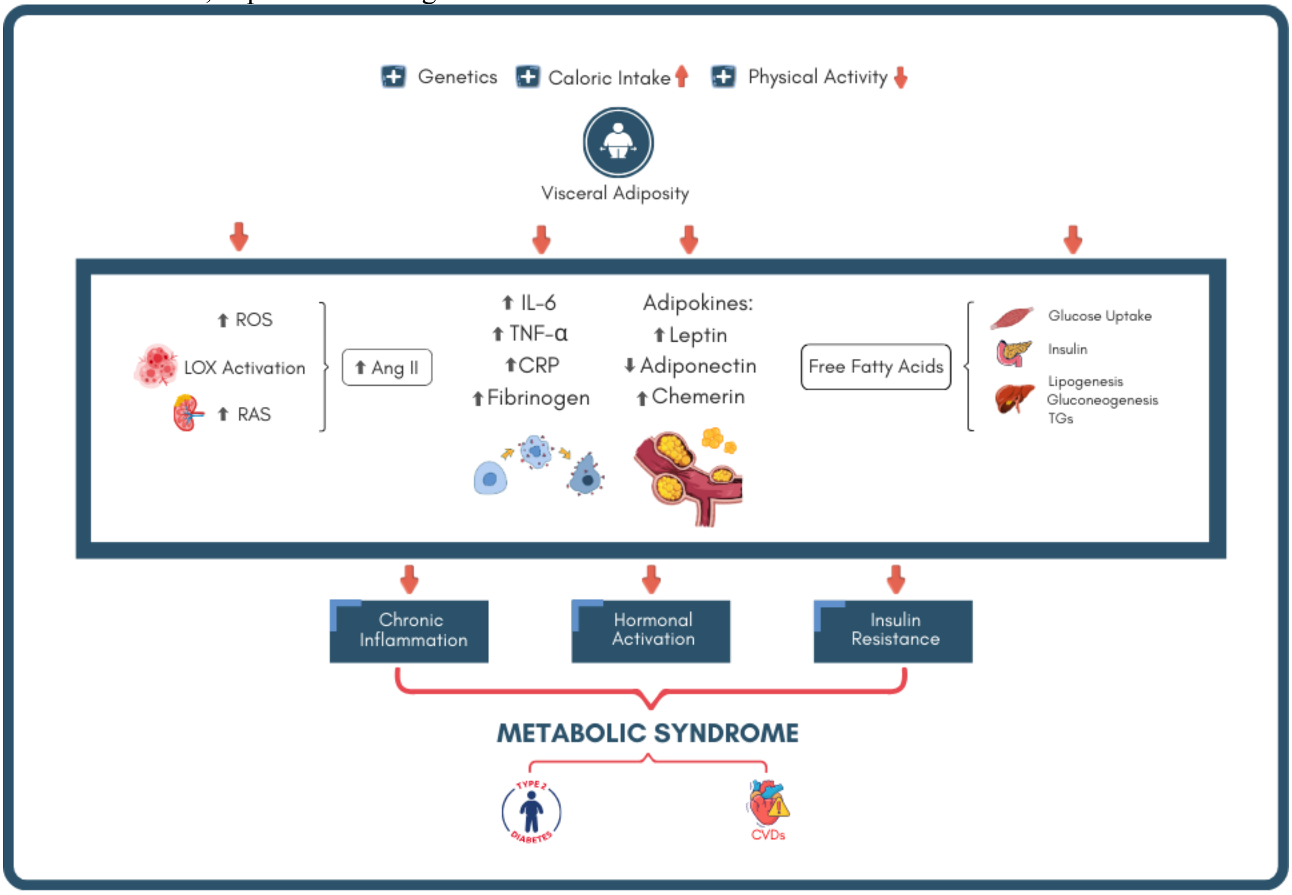

Figure 1. Pathophysiological mechanism of Metabolic Syndrome. The illustration has been redrawn and adapted from Fahed et al., 2021[2]

Definition and Formula of the LAP Index

The LAP index is an alternative biomarker developed to reflect visceral fat accumulation, which is directly related to metabolic risks, including MetS, T2DM, and cardiovascular disease. Introduced by Kahn in 2005, this index combines WC and TG to assess metabolically active visceral lipid accumulation, which plays a role in insulin resistance and other metabolic disorders.[33–36] The advantage of LAP lies in its ease of calculation and its ability to replace imaging techniques such as Computed Tomography Scan (CT scan) or Magnetic Resonance Imaging (MRI) for diagnosing visceral fat.[21,37–40]

The LAP index is calculated differently for men and women to account for physiological differences in fat distribution and the associated metabolic risk. Men tend to accumulate more visceral fat, which is metabolically active and closely linked to insulin resistance and dyslipidemia, whereas women generally have more subcutaneous fat, which has a milder metabolic effect. The LAP formula uses WC minus a reference value (65 for men, 58 for women), multiplied by TG levels. The constants 65 and 58 represent the reference WC of a healthy or lean population, below which WC contributes minimally to metabolic risk. By subtracting these reference values, the formula emphasizes WC above the healthy baseline, making LAP a more accurate indicator of gender-specific metabolic risk due to visceral fat accumulation.[36,41]

The formula is as follows:

LAP Index Formula:

Men : WC (cm) – 65 x TG (mmol/L)[42]

Women : WC (cm) – 58 x TG (mmol/L)[42]

Description:

TG = Triglycerides (mmol/L)

WC = Waist Circumference (cm)

Physiological Basis and Mechanism Linking the LAP Index with Metabolic Syndrome

The LAP index is an indicator developed to reflect visceral lipid accumulation through the WC component, which is metabolically active and closely related to insulin resistance and chronic inflammation.[43–45] Another component of the LAP index is TG, which acts as a marker of atherogenic dyslipidemia and reflects lipid metabolism disorders, a condition often found in individuals with

IR.[46–48] By combining visceral fat accumulation and dyslipidemia, the LAP index reflects two critical components in the pathogenesis of MetS. The involvement of mechanisms such as IR, chronic inflammation, and lipid metabolism dysfunction makes the LAP index a relevant and physiological indicator for diagnosing MetS risk, especially in populations with abdominal obesity.[19,29]

WC, as an indicator of visceral fat, describes the accumulation of fat around organs such as the liver, pancreas, and intestines.[49] This fat produces bioactive molecules such as FFAs, proinflammatory cytokines such as Interleukin-6 (IL-6) and Tumor Necrosis Factor-alpha (TNF-α), and adipokines (leptin, adiponectin), which promote IR and systemic inflammation.[50,51] Visceral fat also has a high rate of lipolysis, releasing excessive FFAs into the portal vein, which stimulates gluconeogenesis and hepatic lipogenesis, increasing TG synthesis and the production of very low-density lipoprotein (VLDL). FFAs and cytokines such as TNF-α disrupt insulin signalling pathways by inhibiting the phosphorylation of insulin receptor substrate-1 (IRS-1) and reducing the effectiveness of the phosphoinositide 3-kinase/protein kinase B (PI3K/Akt) pathway.[52,53] In addition, IL-6 inhibits the expression of Glucose Transporter Type 4 (GLUT4), thereby reducing glucose uptake by muscles and adipose tissue. At the same time, oxidative stress activates the c-Jun N-terminal Kinase (JNK) and Inhibitor of kappa B kinase beta (IKK-β) pathways, which further exacerbate insulin signalling impairment. The decrease in anti-inflammatory adiponectin levels also worsens IR, which in the long term leads to compensatory hyperinsulinemia and failure to maintain normoglycemia.[54,55]

Increased TG in IR conditions is not only a metabolic marker, but also contributes to atherogenic dyslipidemia through increased VLDL synthesis and cholesteryl ester transfer protein (CETP) enzyme activity.[56,57] This process produces TG-rich HDL that is easily destroyed and small, dense LDL that is susceptible to oxidation, contributing to an increased risk of atherosclerosis. The accumulation of TG and VLDL in peripheral tissues such as the liver and muscles causes lipotoxicity through the formation of diacylglycerol (DAG) and ceramide, which activate protein kinase C (PKC) and inhibit Akt, thereby disrupting IRS-1 phosphorylation and worsening IR.[58]

The negative cycle between high IR and TG not only worsens glucose and lipid metabolism but also activates the sympathetic nervous system and RAAS, causing an increase in blood pressure.[59] Therefore, WC and TG in the LAP index reflect molecular interactions involving IR and chronic inflammation—two key mechanisms underlying elevated blood glucose, blood pressure, decreased HDL, and central obesity. LAP not only describes overall metabolic risk, but also has potential as a lifestyle-based preventive screening tool, including dietary and physical activity interventions from an early stage.

METHOD

This review employs a narrative review method to summarize and evaluate the literature related to the use of the LAP index as an alternative biomarker for diagnosing MetS in the global population. The literature was obtained through a targeted search of PubMed, ScienceDirect, and Google Scholar databases. Boolean operators were applied to refine the search, using combinations such as (“lipid accumulation product” OR “LAP index”) AND (“metabolic syndrome” OR “MetS”) AND (biomarker OR “visceral fat” OR “insulin resistance”). The search was conducted in June 2025 and included international publications. The inclusion criteria were original, population-based epidemiological studies in humans published within the last 10 years (2016-2025), evaluating the relationship between the LAP index and MetS as a predictive, screening, or diagnostic tool, and presenting quantitative data such as Area Under Curve (AUC) values, sensitivity (Sn), specificity (Sp), and cutoff values.

Articles were selected in stages through the review of titles, abstracts, and full texts to assess their eligibility based on the inclusion criteria. The screening and selection process was supported by the Rayyan web-based application to organize records and assist in identifying studies that met the eligibility criteria. All selected studies were assessed for methodological rigor and relevance to the research objectives. Final decisions regarding study inclusion were made collectively by all authors to ensure objectivity and alignment with the review objectives. Articles that passed the full-text review were then evaluated descriptively, including study population characteristics, research design, parameters used, diagnostic values, and principal conclusions. The data were subsequently summarized in a comparative table to facilitate analysis and the drawing of conclusions. The detailed process of literature identification, screening, eligibility assessment, and final study inclusion is presented in Figure 2.

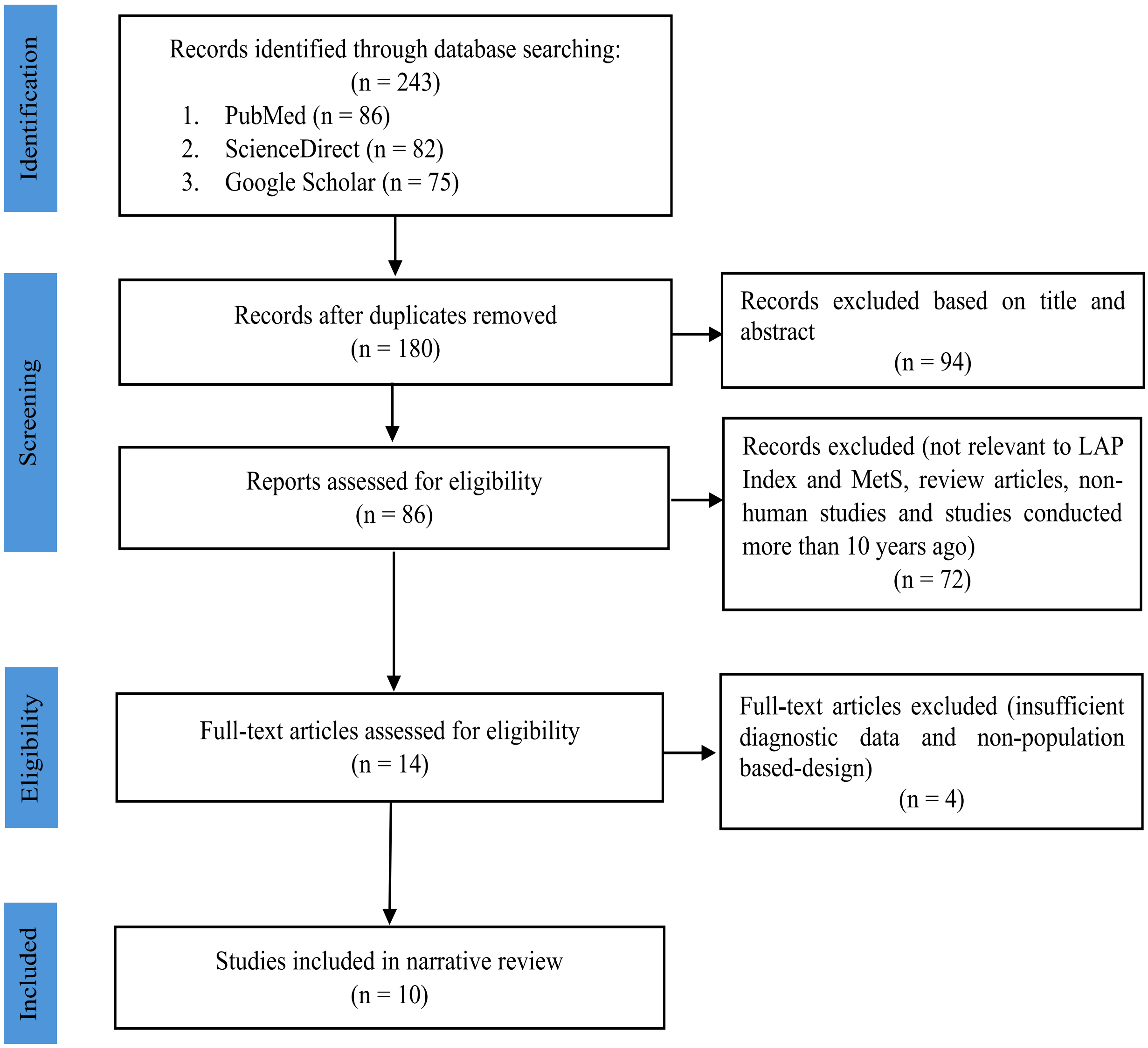

Figure 2. Flow Diagram of Literature Search and Study Selection

RESULT

This section presents a summary of ten epidemiological studies evaluating the diagnostic performance of the LAP index as a biomarker in diagnosing MetS in various populations. The studies include diverse populations, such as adults, adolescents, the elderly, and high-risk groups like women with polycystic ovary syndrome (PCOS). Geographically, the studies encompass various global regions, with the majority originating from Asia and the Middle East, including China, India, Saudi Arabia, and Turkey. Other regions represented include the United States (North America), Brazil (South America), and Italy (Europe). This diversity indicates that the LAP index has been evaluated across a broad range of populations, supporting its potential for global use in the early detection of MetS.

Most studies used a cross-sectional design and compared the diagnostic accuracy of the LAP index against various other anthropometric and metabolic biomarkers. Generally, most studies show an Area Under the Curve (AUC) value greater than 0.850, both in male and female groups, with sensitivity ranging from 59.1% to 100% and specificity ranging from 65.27% to 93.60%, with most Sn and Sp values exceeding 80%. Meanwhile, cutoff values vary depending on population characteristics. Some studies also indicate that the predictive performance of the LAP index is superior to or comparable with that of other biomarkers. A comprehensive summary of study characteristics, population, analytical methods, and key findings from each study is presented in Table 1. Information on the diagnostic value of the LAP index in diagnosing MetS is presented separately in Table 2.

Table 1. Summary of Characteristics and Main Findings of Epidemiological Studies Evaluating LAP Index as a Biomarker for Metabolic Syndrome

No.	Study	Design	Population	Biomarkers	Objective	Main Findings
1.	Enhanced Predictive Value of Lipid Accumulation Product for Identifying Metabolic Syndrome in the General Population of China[19]	Cohort	Adults aged 20–70 years, China	LAP, BMI, WC, WHR, and WHtR	Evaluating the accuracy of LAP and predictive values for identifying MetS compared to other obesity indicators.	LAP, compared to other markers of obesity, is a more accurate predictor of MetS.
2.	Obesity and lipid-related parameters for predicting metabolic syndrome in the Chinese elderly population[26]	Cross-sectional	Elderly individuals aged ≥ 60 years, China	LAP, BMI, WHtR, TG/HDL-C, and VAI	Evaluating the predictive ability of five parameters related to obesity and lipids in identifying MetS.	LAP is a superior predictor of MetS in men compared to VAI, TG/HDL-C, WHtR, and BMI.
3.	Performance of Two Novel Obesity Indicators for the Management of Metabolic Syndrome in Young Adults[4]	Cross-sectional	Young adults aged 19–24, China	VAI and LAP	Understanding the performance of VAI and LAP in predicting MetS.	LAP is a simpler indicator that is valuable for screening MetS.
4.	Identification of metabolic syndrome using lipid accumulation product and cardiometabolic index based on NHANES data from 2005 to 2018[23]	Cohort	Adults aged ≥ 20 years, United States	CMI, LAP, WC, BMI, WHtR, TC/HDL, and LDL/HDL	Assessing the discriminatory value of new obesity markers, particularly LAP and CMI, with MetS.	Compared to other measures of obesity, LAP and CMI demonstrate superior diagnostic accuracy for MetS in both men and women**.**
5.	Predicting metabolic syndrome by lipid accumulation product, visceral adiposity index, and body roundness index in Brazilian rural workers[60]	Cross-sectional	Brazilian rural workers aged 18-59 years, Brazil	LAP, VAI, and BRI	Evaluating the predictive capacity of three anthropometric indices for identifying MetS.	LAP and BRI are reliable and affordable MetS screening tools, suitable for rural areas with limited resources.
6.	The Lipid Accumulation Product Index (LAP) and the Cardiometabolic Index (CMI) Are Useful for Predicting the Presence and Severity of Metabolic Syndrome in Adult Patients with Obesity[29]	Cohort	Adults aged ≥ 18 years with a BMI ≥ 35 kg/m², Italy	BAI, LAP, and CMI	Evaluating the diagnostic accuracy of BAI, LAP, and CMI.	LAP and CMI performed better than BAI in detecting MetS in both the general obese population and in male/female subgroups.
7.	Sex-Specific Cut-Offs of Seven Adiposity Indicators and Their Performance in Predicting Metabolic Syndrome in Arab Adults[61]	Cross-sectional	Adults, Arab Saudi	LAP, VAI, WTI, DAI, BRI, ABSI, BMI, DAI, BRI, WAIST, BAI, AI, CRI	Assess several indicators of adiposity and their effectiveness in predicting MetS and identify their cut-off values among general Saudi adults.	The LAP and WTI performed well in both genders, with a superior ability to identify MetS in males, and could be used to predict MetS in Saudi adults.

Table 1. Summary of Characteristics and Main Findings of Epidemiological Studies Evaluating LAP Index as a Biomarker for Metabolic Syndrome (Continue…)

No.	Study	Design	Population	Biomarkers	Objective	Main Findings
8.	Predicting metabolic syndrome by visceral adiposity index, body roundness index, dysfunctional adiposity index, lipid accumulation product index, and body shape index in adults[62]	Cross-sectional	Adults aged 18-60, Turkey	VAI, DAI, LAP, BRI, glucose, lipid biomarkers, and blood pressure levels	To compare anthropometric measurements and indices for the prediction of MetS.	The LAP index and DAI can be used as predictive tools for the early detection of MetS.
9.	Utility of Visceral Adiposity Index and Lipid Accumulation Products to Define Metabolically-Unhealthy Polycystic Ovary Syndrome in Asian Indian Women - A Cross-Sectional Study[63]	Cross-sectional	Women with polycystic ovary syndrome (PCOS), India	VAI and LAP	Evaluating VAI and LAP performance in women with PCOS and correlating it with metabolic and endocrine markers.	A VAI cutoff value ≥ 2.76 and a LAP cutoff value ≥ 48.06 can be used as markers to predict MetS among women with PCOS.
10.	Lipid accumulation product is a better predictor of metabolic syndrome in Chinese adolescents: a cross-sectional study[64]	Cross-sectional	Adolescents aged 13-18, China	LAP	Assessing the predictive power and discriminatory ability of non-traditional lipid profiles for MetS.	The LAP index is a simple and efficient tool to identify individuals with MetS in Chinese adolescents.

Abbreviations:
LAP, lipid accumulation product; BMI, Body Mass Index; WC, Waist Circumference; WHR, Waist-to-Hip Ratio; WHtR, Waist-to-Height Ratio; VAI, Visceral Adiposity Index; BRI, Body Roundness Index; BAI, Body Adiposity Index; CMI, Cardiometabolic Index; TC/HDL, Total Cholesterol to High-Density Lipoprotein Ratio; LDL/HDL, Low-Density Lipoprotein to High-Density Lipoprotein Ratio; WTI, Waist-Triglyceride Index; DAI, Dysfunctional Adiposity Index; ABSI, A Body Shape Index; AI, Atherogenic Index; CRI, Cardiovascular Risk Index; TG/HDL-C, Triglyceride to High-Density Lipoprotein Cholesterol Ratio.

Table 2. Diagnostic Accuracy of LAP Index in Predicting Metabolic Syndrome in Reviewed Studies

No.	Study	AUC Value (95% CI)		Cutoff		Sn (%)		Sp (%)	
		Men	Women	Men	Women	Men	Women	Men	Women
1.	Enhanced Predictive Value of Lipid Accumulation Product for Identifying Metabolic Syndrome in the General Population of China[19]	0.901 (0.895–0.906) Very Good Value	0.898 (0.893–0.902) Good Value	36.06	34.95	81.91	80.93	81.06	83.04
2.	Obesity and lipid-related parameters for predicting metabolic syndrome in Chinese elderly population[26]	0.897 (0.885–0.907) Good Value	0.875 (0.864–0.886) Good Value	26.35	31.04	85.09	79.17	79.31	80.69
3.	Performance of Two Novel Obesity Indicators for the Management of Metabolic Syndrome in Young Adults[4]	0.963 (0.912-1.000) Very Good Value	0.931 (0.829-1.000) Very Good Value	20.10	13.70	100	100	85.20	75.50

Table 2. Diagnostic Accuracy of LAP Index in Predicting Metabolic Syndrome in Reviewed Studies (Continue…)

No.	Study	AUC Value (95% CI)		Cutoff		Sn (%)		Sp (%)	
		Men	Women	Men	Women	Men	Women	Men	Women
4.	Identification of metabolic syndrome using lipid accumulation product and cardiometabolic index based on NHANES data from 2005 to 2018[23]	0.884 (0.876-0.893) Good Value	0.878 (0.870-0.887) Good Value	52.76	49.87	59.10	58.20	75.28	75.77
5.	Predicting metabolic syndrome by lipid accumulation product, visceral adiposity index, and body roundness index in Brazilian rural workers[60]	0.885 Good Value		33.84		69.52		82.91	
6.	The Lipid Accumulation Product Index (LAP) and the Cardiometabolic Index (CMI) Are Useful for Predicting the Presence and Severity of Metabolic Syndrome in Adult Patients with Obesity[29]	0.810 (0.750–0.870) Good Value	0.820 (0.800–0.840) Good Value	101.5	87.39	70.81	81.97	64.27	85.45
7.	Sex-Specific Cut-Offs of Seven Adiposity Indicators and Their Performance in Predicting Metabolic Syndrome in Arab Adults[61]	0.877 (0.840–0.909) Good Value	0.840 (0.803–0.872) Good Value	46.2	49.82	85.63	68.53	76.26	82.38
8.	Predicting metabolic syndrome by visceral adiposity index, body roundness index, dysfunctional adiposity index, lipid accumulation product index, and body shape index in adults[62]	0.915 (0.878-0.953) Very Good Value		44.52		84.80		84.70	
9.	Utility of Visceral Adiposity Index and Lipid Accumulation Products to Define Metabolically-Unhealthy Polycystic Ovary Syndrome in Asian Indian Women - A Cross-Sectional Study[63]	0.860 (0.81–0.92) Good Value		48.06		79.55		79.49	
10.	Lipid accumulation product is a better predictor of metabolic syndrome in Chinese adolescents: a cross-sectional study[64]	0.990 (0.980-0.999) Very Good Value	0,964 (0.944-0.983) Very Good Value	38.03	28.91	100	100	93.60	88.90

Abbreviations:
AUC, area under the curve; CI, confidence interval; Sn, sensitivity; Sp, specificity; AUC values are classified as follows: very weak (0.5–0.6), weak (0.6–0.7), moderate (0.7–0.8), good (0.8–0.9), and very good (>0.9) based on established diagnostic accuracy criteria.[65]

DISCUSSION

The LAP index is a promising alternative biomarker for the early detection of MetS, as it effectively represents visceral fat accumulation and dyslipidemia, two key components in the pathogenesis of MetS. Its constituent components, WC and TG levels, synergistically reflect the metabolic dysfunction underlying this condition.[62,66] Although the pathogenesis of MetS is not yet fully understood, several studies support the notion that IR originating from central obesity is a critical mechanism in the development of MetS. On the other hand, dyslipidemia can cause the accumulation of lipids and their metabolites, which disrupt the function of pancreatic β cells, induce IR, and subsequently facilitate the development of various components of MetS, leading to metabolic complications.[67,68] As such, the role of the LAP index in identifying and monitoring metabolic diseases has gradually gained attention in recent years.

Based on a review of 10 epidemiological studies, the LAP index consistently demonstrated high diagnostic accuracy in identifying MetS in various population groups in both men and women. The majority of studies reported AUC values indicating good to excellent discriminatory ability.[4,19,23,26,60,62–64] For reference, biomarkers with the highest AUC values are considered the most reliable, with values closer to 1 indicating more optimal classification accuracy. Generally, AUC values are classified as very weak (0.5–0.6), weak (0.6–0.7), moderate (0.7–0.8), good (0.8–0.9), and very good (>0.9).[65] In addition to the AUC value, high and balanced Sn and Sp are also important parameters. However, they often show an inverse relationship, with an increase in one parameter tending to be accompanied by a decrease in the other.[69,70] Although there is no universal standard limit, values above 70% are generally considered acceptable, and > 80% indicates good accuracy.[71–73]

Supporting the ability of the LAP index as an alternative biomarker for MetS, several studies have shown the excellent diagnostic performance of the LAP index. A general population study in China reported an AUC of 0.901 in men and 0.898 in women, with Sn and Sp of approximately 81–83%. Similar findings were also reported in another study of elderly individuals, which recorded an AUC greater than 0.870 with high accuracy, particularly in men.26 Among younger age groups, including adolescents and young adults, the LAP index also demonstrated high effectiveness. A study on adolescents in China reported AUC values approaching perfection, with 0.990 in men and 0.964 in women, accompanied by Sn and specificity Sp values exceeding 88% in both sexes. These findings suggest that the LAP index has the potential to be used as a biomarker for MetS screening across various age groups.[64]

When compared with various other alternative biomarkers such as body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), visceral adiposity index (VAI), body circumference index (BRI), body adiposity index (BAI), cardiometabolic index (CMI), and triglyceride-to-high-density lipoprotein cholesterol ratio (TG/HDL-C) from several studies, the LAP index generally demonstrates comparable or superior predictive performance, particularly because it only requires two simple parameters.[4,19,23,26,29,60–63]

As shown in the NHANES study (2005–2018), the LAP index demonstrates better diagnostic accuracy than BMI, WC, WHtR, and cholesterol ratio levels.[23] Obesity is a clinical condition characterised by an imbalance in lipid and glucose metabolism, as well as the accumulation of fat in subcutaneous adipose tissue and visceral adipose tissue in various parts of the body.[74] Numerous studies have highlighted the crucial role of visceral fat in the development of metabolic disorders and IR.[75] Meanwhile, although BMI is a standard tool for assessing obesity, its limitation lies in its ability to only estimate total body fat without taking into account its distribution or localisation. Fat distribution is critical because it has different metabolic implications.[76]

Other measurements, such as WC and WHtR, have been recommended because of their better predictive value compared to BMI.[77] However, these two biomarkers are unable to distinguish between subcutaneous and visceral fat accumulation accurately. On the other hand, the ratio of total cholesterol to HDL (TC/HDL) and LDL to HDL (LDL/HDL) is more closely associated with the risk of atherosclerosis and provides an exclusive reflection of blood lipid profiles.[78] Thus, the LAP index is a highly valuable non-invasive and practical method for assessing visceral fat, which is a significant risk factor for MetS and other related diseases. This index provides a more accurate indication of metabolic risk than other biomarkers.[79]

Meanwhile, the effectiveness of the LAP index is also evident in populations with limited health services and infrastructure. A rural study in Brazil showed an AUC > 0.800, indicating the potential of the LAP index as an affordable and accurate biomarker, surpassing indices such as VAI and BRI. This diagnostic performance is supported by a strong correlation between the LAP index and TG, as well as a moderate correlation with WC, both of which are also part of the diagnostic criteria for MetS.[60] A study also found that combining the LAP index with other indices such as CMI, BAI, WTI, and VAI can improve accuracy, confirming its flexibility as a single biomarker or as a complement to MetS.[29]

The ability of the LAP index to identify MetS has been widely proven, including in populations with specific health conditions such as women with Polycystic Ovary Syndrome (PCOS). A study in India showed that the LAP index had an AUC value of 0.860 in diagnosing MetS in women with PCOS, indicating good diagnostic performance. The study also stated that the LAP index was significantly correlated with TG and the homeostatic model assessment of insulin resistance (HOMA-IR), reflecting insulin resistance.[63] Furthermore, the LAP index is also closely related to hormonal parameters that reflect the severity of PCOS, notably the Free Androgen Index (FAI), which shows a powerful positive correlation, indicating its potential as an indicator of hyperandrogenism, a characteristic of PCOS that contributes to metabolic risk. These findings suggest that the LAP index not only reflects visceral fat accumulation but also captures the underlying endocrine dysfunction associated with metabolic disorders in PCOS.[63]

The consistency of findings across regions such as Asia, the Middle East, South America, and Europe supports the universal nature of the LAP index.[4,19,23,26,29,60–64] However, it should be noted that differences in AUC values and cutoff points between studies may be due to variations in population characteristics, including sociodemographic, genetic, environmental, and lifestyle factors such as diet and physical activity levels, as well as differences in the diagnostic criteria for MetS used. Therefore, local validation of cutoff values adjusted to population characteristics is important to enhance the accuracy and clinical relevance of the LAP index as a screening tool for MetS, as well as to minimise the risk of over- or underdiagnosis.[80]

Based on existing evidence, the LAP index has excellent potential to be implemented as an initial screening tool for MetS, particularly in primary healthcare facilities in developing countries such as Indonesia. The LAP index offers advantages in terms of ease of calculation, requiring only WC and TG, as well as low cost. These two parameters are generally available in routine examinations, enabling the widespread and efficient application of the LAP index. As a metabolic risk indicator, LAP is also more practical compared to complex laboratory-based methods or imaging technologies. Integrating LAP into MetS early detection programs can strengthen the identification of high-risk individuals before the onset of serious complications such as CVD and T2DM. With early identification, lifestyle interventions such as dietary adjustments and physical activity can be targeted more effectively to prevent the accumulation of visceral fat.

Although the results of this review support the potential of the LAP index as an accurate alternative biomarker for the early detection of metabolic syndrome (MetS), several limitations should be considered. Most of the reviewed studies employed cross-sectional designs, which preclude the establishment of causal relationships between the LAP index and the development of MetS in a longitudinal context. In addition, significant heterogeneity was observed across the analyzed populations, including differences in demographic, genetic, and lifestyle characteristics, which may influence the validity of cutoff values and limit the universal applicability of the findings.

Nevertheless, this population heterogeneity also highlights the relevance and feasibility of the LAP index across diverse settings. Because the LAP index relies on simple anthropometric measurements and routinely available biochemical parameters, namely WC and TG levels, it is particularly suitable for use in low-income and developing countries, where limited resources, uneven infrastructure, and restricted access to advanced diagnostic tools pose challenges for large-scale population screening. Consequently, the LAP index may serve as a practical, simple, and cost-effective screening tool for the early detection of MetS. However, variability in population characteristics underscores the need for population-specific validation and the establishment of appropriate cutoff values to ensure its accuracy and clinical applicability across different socioeconomic and ethnic contexts. Therefore, further research employing stronger prospective designs, such as longitudinal studies, and validity testing in more representative populations, particularly in specific developing countries, is needed to ensure the effectiveness and clinical relevance of the LAP index.

CONCLUSION

Based on a review of various global epidemiological studies, the LAP index demonstrates strong potential as a simple, affordable, and physiologically relevant biomarker for the early detection of MetS. With its high diagnostic accuracy across diverse population groups and reliance on easily accessible parameters, this index can be integrated into screening programs in primary healthcare settings. The LAP index also supports preventive strategies through lifestyle interventions, including targeted nutritional strategies and behavioral modifications. Nevertheless, further studies with stronger designs (e.g., longitudinal studies) are needed to validate appropriate cutoff points tailored to diverse population characteristics, particularly in developing countries with limited healthcare services or infrastructure.

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