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Metabolic syndrome as a risk factor associated with acute myocardial infarction in young adults: a systematic review with meta-analysis

Síndrome metabólica como fator de risco associado ao infarto agudo do miocárdio em adultos jovens: uma revisão sistemática com metanálise

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ABSTRACT

Introduction: Acute myocardial infarction (AMI) in young adults is a growing public health problem, due to its functional and socioeconomic impact on this population. Among the risk factors, metabolic syndrome (MetS) stands out for its association with a higher incidence and worse prognosis of AMI. **Objective:** The objective of this systematic review with meta-analysis was to investigate the relationship between MetS and AMI in adults and young adults. **Material and Methods:** The search was conducted in the PubMed, Embase, Scopus, SciELO and Web of Science databases, without language or period restrictions. Observational studies that evaluated individuals in the age range between 18 and 50 years, diagnosed with AMI and MetS according to NCEP ATP III, IDF, or WHO criteria, were included. Article selection and data extraction were performed using the Rayyan QCRI platform, the risk of bias was assessed using the ROBINS-I tool, and statistical analyses were conducted using RStudio 2023.12.0. **Results:** Fifteen studies met the criteria, totaling 3,339 patients with AMI. The association meta-analysis demonstrated that the presence of metabolic syndrome (MetS) was associated with an almost four times greater risk of AMI in young individuals (OR = 3.96; 95% CI: 1.98–7.93), with substantial heterogeneity (I^2 = 68%). The prevalence of MetS in myocardial infarction patients was 54% (95% CI: 49–59) according to the NCEP ATP III criteria, and 58% (95% CI: 49–67) according to the IDF. **Conclusion:** Despite the heterogeneity among the studies, the findings reinforce the strong association between metabolic syndrome and AMI in young adults, highlighting its high prevalence in this population, and may support the development of more effective strategies and public policies to reduce cases of AMI.

Keywords: Myocardial Infarction; Metabolic Syndrome; Young Adult.

RESUMO

Introdução: O infarto agudo do miocárdio (IAM) em adultos jovens é um problema crescente de saúde pública, devido ao seu impacto funcional e socioeconômico nessa população. Dentre os fatores de risco, a síndrome metabólica (SM) destaca-se por sua associação com maior incidência e pior prognóstico de IAM. **Objetivo:** O objetivo desta revisão sistemática com metanálise foi investigar a relação entre SM e IAM em adultos e adultos jovens. **Material e Métodos:** A busca foi realizada nas bases de dados PubMed, Embase, Scopus, SciELO e Web of Science, sem restrições de idioma ou período. Foram incluídos estudos observacionais que avaliaram indivíduos na faixa etária entre 18 e 50 anos, diagnosticados com IAM e SM de acordo com os critérios do NCEP ATP III, IDF ou OMS. A seleção dos artigos e a extração de dados foram realizadas utilizando a plataforma Rayyan QCRI, o risco de viés foi avaliado pela ferramenta ROBINS-I e as análises estatísticas foram conduzidas utilizando o RStudio 2023.12.0. **Resultados:** Quinze estudos atenderam aos critérios, totalizando 3.339 pacientes com IAM. A metanálise de associação demonstrou que a presença de síndrome metabólica (SM) esteve associada a um risco quase quatro vezes maior de IAM em indivíduos jovens (OR = 3,96; IC 95%: 1,98–7,93), com heterogeneidade substancial (I^2 = 68%). A prevalência de SM em pacientes com infarto do miocárdio foi de 54% (IC 95%: 49–59) segundo os critérios do NCEP ATP III e de 58% (IC 95%: 49–67) segundo os critérios da IDF. **Conclusão:** Apesar da heterogeneidade entre os estudos, os achados reforçam a forte associação entre síndrome metabólica e IAM em adultos jovens, destacando sua alta prevalência nessa população, e podem subsidiar o desenvolvimento de estratégias e políticas públicas mais eficazes para reduzir os casos de IAM.

Palavras-chave: Infarto do Miocárdio; Síndrome Metabólica; Adulto Jovem.

INTRODUCTION

Acute Myocardial Infarction (AMI) has been identified as a significant public health concern, given the substantial social, economic and clinical implications of this early event, as well as the impacts generated by its sequelae.[1] Despite the significant decline in cardiovascular mortality observed in recent decades, recent studies indicate that AMI has not decreased among young adults, remaining stable or even increasing in some countries. This phenomenon stands in contrast to the behavior typically observed in older age groups and has been identified as an emerging public health concern.[2]

The ARIC (Atherosclerosis Risk In Communities) study revealed that approximately 30% of patients hospitalized for AMI (Acute Myocardial Infarction) in a US hospital between 1995 and 2014 were between 35 and 54 years old.[3] Conversely, over the course of a decade (2007-2017), there was a subtle rise in hospital admissions due to AMI in the younger population, particularly among non-white females. This was accompanied by an increase in the prevalence of cardiovascular complications following AMI.[4]

According to the extant scientific literature, the primary cause of myocardial infarction (MI) in young adults is early atherosclerosis, accounting for approximately 90% of cases.[5] It is evident that a number of risk variables are prevalent among this population. These include, but are not limited to, smoking, dyslipidemia, obesity, hypertension, diabetes mellitus, and a family history of premature coronary artery disease.[6,7] In this regard, certain data demonstrate that metabolic syndrome is associated with a considerable escalation in the risk of myocardial infarction (OR = 2.20) and also as a factor of poorer prognosis in patients who have previously experienced a heart attack,[8] resulting in a higher rate of cardiovascular mortality when compared to patients without metabolic syndrome.[9]

This study investigates the association between metabolic syndrome (MetS) and acute myocardial infarction (AMI) in young adults. Given its impact on morbidity and mortality in this economically active population, and the preventable nature of MetS, this analysis may support the development of effective primary prevention strategies.

MATERIAL AND METHODS

This systematic review with meta-analysis was prepared according to the methodological guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA),[10] structured based on two comparative arms, with the objective of synthesizing the available evidence on the association between MetS and AMI in young adults. The protocol of this study was registered in the International Prospective Register of Systematic Reviews (PROSPERO) under number CDR420251018601.

Eligibility criteria

The guiding inquiry was formulated based on the PICO strategy: P (population): only individuals aged 18 to 50 years with acute myocardial infarction (AMI) were included in the study; I (intervention/exposure): the presence of metabolic syndrome was documented; C (comparator): the absence of metabolic syndrome was recorded; O (outcome): the occurrence of AMI was monitored. According to the aforementioned structure, the objective was to ascertain whether metabolic syndrome functions as an associated factor for the development of acute myocardial infarction (AMI) in young adults.

Information source and search strategy

The literature search was conducted systematically in the PubMed, Embase, Scopus, Scielo, and Web of Science databases, with no restrictions on language or publication date. A combination of controlled descriptors (DeCS/MeSH) and free terms, in conjunction with Boolean operators "AND" and "OR" was employed in the search strategy. The search strategy for each database is outlined in greater detail in Appendix 1.

Observational studies (cohort, case-control, and cross-sectional) that addressed the association between metabolic syndrome and acute myocardial infarction (AMI) in individuals aged 18 to 50 years were included, results from older age groups are not included. Studies that did not include AMI as a primary or secondary outcome, as well as those that did not provide sufficient data to extract measures of association, were excluded from the analysis.

Selection process

The selection of studies was conducted independently by two reviewers (BS, AJ) using the Rayyan QCRI online platform.[11] The screening process was executed in two stages. Initially, a preliminary evaluation was conducted in which titles and abstracts were reviewed. Subsequently, a more comprehensive evaluation was conducted, entailing the review of potentially eligible articles in their entirety. Conflicts of opinion among the reviewers were addressed with the involvement of a third reviewer (SC) until a consensus was achieved. The data extraction process was executed through the utilization of Microsoft Excel spreadsheets, arranged in accordance with a standardized protocol.

Assessment of study risk of bias

The risk of bias assessment was conducted using the Risk of Bias in Non-randomized Studies – of Interventions (ROBINS-I) tool. Consequently, two reviewers (BS, AJ) independently evaluated the methodological quality of the included studies.[12]

Meta-analysis

The statistical analyses were conducted in accordance with the recommendations of the Cochrane Collaboration[13] and the PRISMA guidelines.[10] The meta-analyses were conducted in RStudio 2023.12.0 (R Foundation for Statistical Computing, Vienna, Austria)[14] using the "meta" package.[15] A meta-analysis of proportions was performed using a random-effects model with logit transformation (PLOGIT). The analysis was fitted using a generalized linear mixed model (GLMM),[16] with between-study variance (τ^2) estimated by restricted maximum likelihood (REML).[17] Confidence intervals for individual study proportions were calculated using the Clopper–Pearson method.[18]

Additionally, a meta-analysis of association was performed using odds ratios (ORs) as the measure of effect, along with their respective 95% confidence intervals (95% CIs).[19] Statistical heterogeneity was assessed using Cochran's Q test and the I^2 statistic.[20] Values greater than 25% were considered indicative of substantial heterogeneity.[20] The adjustment analysis and explanation of heterogeneity was performed based on the analysis of subgroups (moderators) according to the continent in which the study was conducted.[16]

Assessment of the quality of evidence

The quality of the evidence was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) tool by two researchers (BS, AJ). The quality of evidence can be downgraded or upgraded following an assessment of the following five criteria: risk of bias, publication bias, imprecision, inconsistency, and indirect evidence.[21,22] The GRADE quality of evidence can be seen in greater detail in Appendix 2.

RESULTS

Study selection

A total of 4.710 studies that met the search criteria were identified in the five databases used (i.e. PubMed, Embase, Scopus, Scielo, and Web of Science). However, 1,050 of these were excluded due to the presence of duplicates, six articles could not be obtained in full even after contacting the authors, and of these, five were excluded. The remaining article was used with data obtained only from the abstract. Following the conclusion of the selection process, a total of 15 studies were included in the present search (see Figure 1).

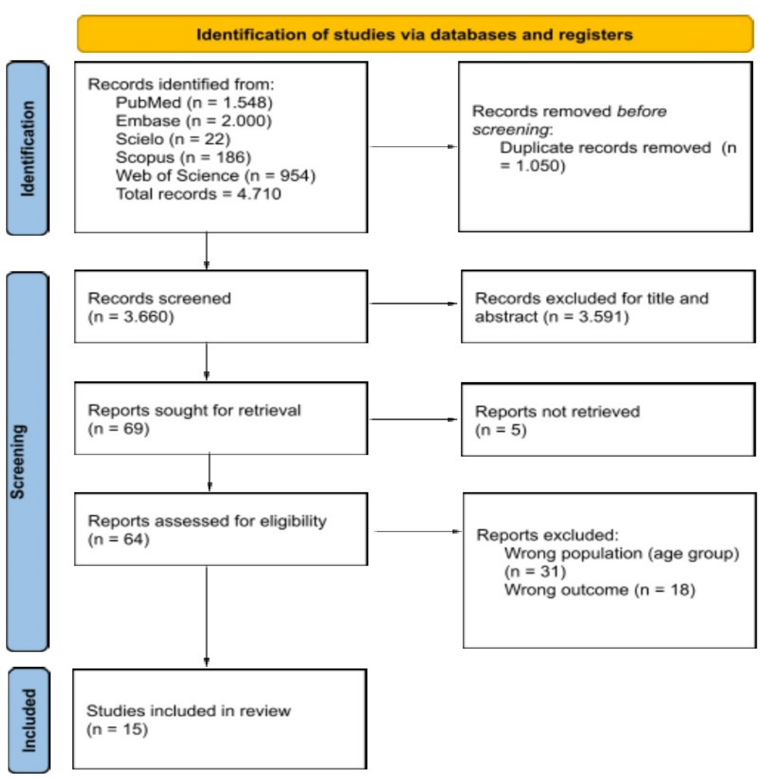

Figure 1: PRISMA flow chart

Study characteristics participants

The studies analysed a total of 3.339 patients with AMI, aged 18 to 50 years,[21] and the majority of patients were male. Furthermore, the studies were conducted on four continents, the majority in Asia, six studies, [23–28] four studies in Africa,[29–32] four in the Americas and finally,[33-36] one in Europe (Table 1).[37] The criteria employed for the diagnosis of metabolic syndrome were derived from the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III), [23,24,26,28,33,34,37] the International Diabetes Federation (IDF), [25,27,35] and the World Health Organization (WHO).[36] However, it should be noted that certain studies classified patients using criteria from both the IDF and NCEP ATP III.[29–32]

Type of studies

Of the studies included in this systematic review, seven were of the cross-sectional variety,[25–31] five were of the case-control variety,[23,24,32,35,37] two were of the retrospective cohort variety,[34,36] and one was of the retrospective observational variety[33] (Box 1).

Risk of bias assessment

The studies were evaluated across the seven ROBINS-I domains, as illustrated in Figure 2, which was generated by Risk-of-Bias Visualization.[38] In the risk of bias analysis, it was observed that, in the first domain, the absence of statistical analyses for possible confounding factors was common in the evaluated studies. In the fourth domain, which addresses intervention deviations, all studies were considered low risk. This is because the intervention in question is MetS and deviations in this parameter were considered unlikely. In addition, the majority of studies in the fifth domain did not present missing data that would have a significant impact on the results. Conversely, in the sixth domain, the majority of studies exhibited a low to moderate risk of bias, given that the primary outcome was AMI and that the majority of these studies employed the criteria established by the American College of Cardiology and/or the European Society of Cardiology. In the seventh domain, the majority of studies were classified as low risk, with the exception of one study, which was categorised as "not reported" due to an absence of evidence indicative of outcome selection.

With respect to the overall risk of bias, two studies were classified as low risk,[35,37] while one was considered moderate risk.[27] In contrast, ten studies presented a serious risk,[24–26,28–34] with the classification of the first domain as "serious" being decisive in this case, due to the significant presence of unanalysed confounding factors. Furthermore, two studies were classified as critical: firstly, due to its status as a synopsis of an event published in the proceedings, with minimal details concerning the research;[36] and secondly, due to the fact that only the article's abstract was available.[23] In the latter, despite the author being contacted, no response was received. Consequently, data extraction for the study was performed exclusively from the abstract, resulting in four domains classified as "not reported" and, thus, an increased risk of bias.

Box 1: Main characteristics of the included studies

Studies	Study design and data source	Nº of patients	Mean age	% male	Selection criteria	Effect measures
Ahmed et al., 2022	Observational cross-sectional study, tertiary care hospital in Karachi, Pakistan. Data collection for 6 months	170	29.84 ± 7.96	57.6%	Patients aged 18-40 with STEMI; exclusions: prior STEMI, prior cardiac surgery, pregnancy >30 days	Prevalence of MetS: 64.7%. Common components: BMI>23 (97.1%), Hypertension (72.4%)
Zarich et al., 2006	Retrospective observational study, Bridgeport Hospital, Connecticut, USA; Data collection from January 1999 to march 2003	165	41.3 ± 4.6	84%	<45 years with AMI; exclusions: cocaine use, incomplete metabolic data	MetS prevalence:38%; MetS and/or diabetes in 61%;

Chung et al., 2007	Retrospective cohort, Lahey Clinic, Massachusetts, USA; Data collection from June 2001 to December 2004	161	18-45	86%	Patients 18-45 with AMI undergoing PCI; MS defined using BMI>28.8; exclusion: not having data on the 5 criteria of the SM.	MS prevalence: 47%; Common components: high HDL (83%) and high triglycerides (78%)
Ranjith et al., 2011	Case-control genetic association study, South Africa. Data collection period not provided	485 patients, 300 controls	≤ 45	86%	AMI patients ≤45 y, Asian Indian; exclusion: previous cardiovascular disease and smoking	The MetS according to NCEP ATP III criteria was diagnosed in 61% of patients, and in 60% of patients according to the IDF criteria.
Ranjith et al., 2007	Cross-sectional observational study, RK Khan Hospital, Durban, South Africa; Data collection from May 1999 to June 2005	389 cases	≤ 45	87%	patients with acute myocardial infarction and ≤45 y, Asian Indian origin	MetS prevalence: 60% (NCEP), 57% (IDF), 69% (NCEP with IDF cutoffs);
Milionis et al., 2007	Case-control study, University of Ioannina, Greece Data collection from January 2004 to January 2006	136 cases, 136 controls	41.2 ± 3.6	94.1%	First-ever ACS, age ≤45, compared to age- and sex-matched healthy controls; exclusions: a previous history of cardiovascular disease, impaired renal function and thyroid dysfunction	MetS prevalence: 40.4% vs 23.5%; OR for ACS: MetS = 1.97 (1.08–3.56; P-value 0.02),
Jain et al., 2021	Observational Cross-sectional study, tertiary care hospital of western Uttar Pradesh, India. Data collection period not provided	98	MetS + mean:: 51.3 ± 12.1 MetS – mean: 56.4 ± 12.2	85,7%	Patients admitted to UTI with AMI diagnosed according to universal criteria	MetS prevalence: 58.16%, in patients under 44 years of age the prevalence was 70%;
Wadhwa et al., 2013	Case control study, India. Data collection period not provided	40 cases, 40 controls	Cases: 39.23 ± 4.80 Controls: 38.9 ± 4.23	*	*	MetS prevalence cases: 47,5% (19 patients) MetS prevalence controls: 20% (8 patients)

Mathiew-Quirós et al., 2017	Case-control study, Mexico. Data collection from December 2014 to July 2015	55 cases, 55 controls	Cases: 41.6 ± 3.9; Controls: 31.8 ± 7.6	Cases: 96.4% Controls: 76.4%	Cases and controls under 47 years of age in the northeast of the country. Cases were patients diagnosed with AMI (incident and primary cases). Controls were individuals without a diagnosis of AMI identified as donors at the same hospital's blood bank	MetS prevalence cases: 83% (46 patients) MetS prevalence controls: 31% (17 patients)
Karn, J.P.L., 2022	Cross-sectional observational study; Cardiology Department, Darbhanga Medical College & Hospital, India. Data collection period not provided	120 patients	MetS+ mean: 52.3 yrs MetS− mean: 48.9 yrs	MetS+: 80% MetS−: 96.2%	Patients diagnosed with ACS, with evidence of myocardial necrosis, associated with ischemic chest pain > 30 minutes (with or without dyspnea), diaphoresis, nausea and/or vomiting, ECG changes or angina lasting ≤ 20 minutes accompanied by ST-segment depression > 1 mm in two or more contiguous leads	MetS prevalence (South Asian-modified NCEP ATP III): 60%
Fernandes R; Forey K, 2023	Retrospective cohort study; Mayo Clinic hospitals (Arizona, Minnesota, Wisconsin). Data collection from October 1, 2015, to December 31, 2018	553	44.4 years	69.1%	Patients aged 18–50 with diagnosis of AMI	MetS prevalence: 61.3% (WHO criteria)

Ramesh et al., 2018	Cross-sectional, case–control study; Department of General Medicine, tertiary care center, India. Data collection from October 2013 to November 2015	51 cases (AMI) and 51 matched controls	42 ± 2.91 years	84.3%	Patients with ≤45 years of age and diagnosed with AMI (for case group). Patients with any recent illness, tissue injury, inflammatory arthritis, chronic kidney disease, iron deficiency anemia, hemochromatosis, liver disease, Hodgkin's disease, leukemia, infection, on non-steroidal anti-inflammatory drugs or statins or niacin use, and women on hormone replacement therapy were not included in the study	MetS prevalence: 62.74% in cases vs 33.33% in controls
Iqbal et al., 2019	Cross-sectional study; Cardiology Department, Bahawal Victoria Hospital, Bahawalpur, Pakistan. Data collection from March 1, 2018, to August 31, 2018	380 patients	53.87 ± 10.42	65.79%	All patients who will be diagnosed on admission as Acute ST segment elevation Myocardial infarction(as per operational definitions). Age limits for both genders are 30 to 70 years	MetS prevalence 43.42% overall 42.0% in males 46.15% in females (No adjusted OR reported)
Ranjith et al., 2008	Cross-sectional genetic association study; Coronary Care Unit, R.K. Khan Hospital, Durban, South Africa. Data collection from January 1999, to January 2008	467	≤45 years	87%	Young patients (≤45 years) of Asian Indian descent admitted with acute myocardial infarction (AMI), defined by Joint ESC/ACC criteria	MetS prevalence (NCEP): 60.4% MetS prevalence (IDF): 59.5%
Ranjith et al., 2009	Cross-sectional study; South Africa. Data collection period not provided	492 cases	≤45 years	86%	Men and women aged 45 years or younger admitted with a diagnosis of AMI	MetS prevalence: NCEP 61%, IDF 60%

Legend: ACC - American College of Cardiology; ACS - Acute Coronary Syndrome; AMI - Acute Myocardial Infarction; BMI - Body Mass Index; ESC - European Society of Cardiology; MetS - Metabolic Syndrome; PCI - Percutaneous Coronary Intervention; STEMI - Acute ST segment elevation myocardial infarction. * Only the article's abstract was used due to the impossibility of accessing the full article. This information was not available from the source used.

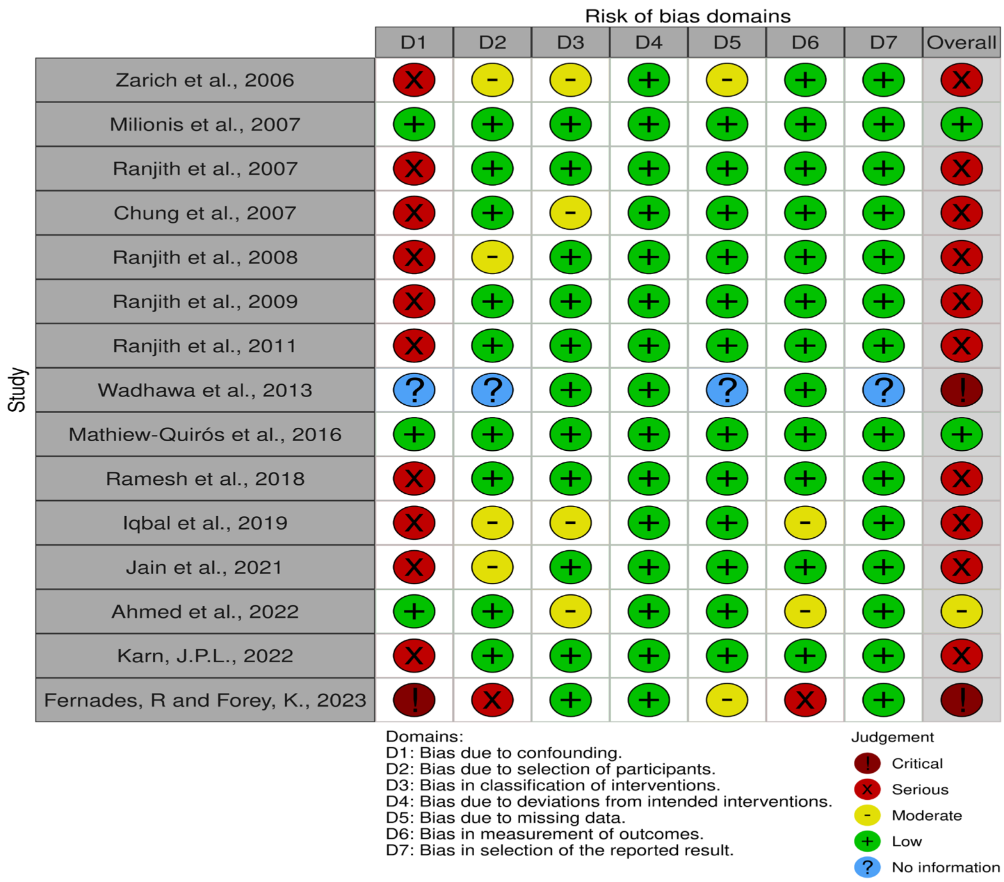

Figure 2: Risk of bias Traffic-light plot

Meta-analysis of Association and Prevalence of AMI

In the meta-analysis of the association between metabolic syndrome and acute myocardial infarction, four studies were analysed,[23,24,35,37] with a total of 564 patients, 282 controls and 282 cases. The degree of evidence according to the GRADE system was moderate [see Appendix 2]. The findings of this study suggest a significant association between the presence of MetS and an elevated risk of AMI in young patients. Utilizing the common effect model, an odds ratio (OR) of 3.41 [95% CI: 2.38–4.89] was observed, while the random effects model exhibited an OR of 3.96 [95% CI: 1.98–7.93]. This indicates that the likelihood of experiencing AMI is more than triple in the presence of MetS. The heterogeneity between studies was high (I^2 = 68.0%), with high variability between studies true effects and a p-value < 0.05 indicating significant heterogeneity (Figure 3).

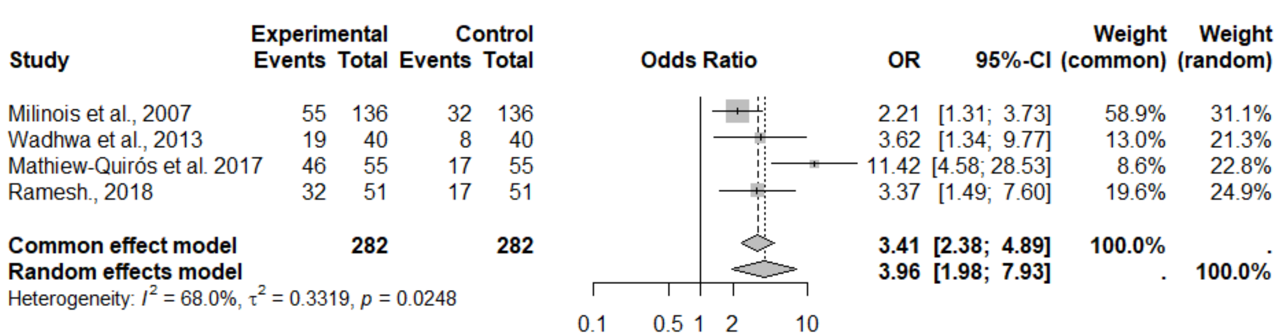

Figure 3: Meta-analysis of the association between acute myocardial infarction and metabolic syndrome

A meta-analysis was conducted to determine the prevalence of metabolic syndrome (MetS) in patients with acute myocardial infarction (AMI). The analysis was based on eleven studies that included a sample of 2,451 individuals.[23,24,26,29-32,35] These studies utilized the NCEP ATP III criteria to define MetS. In contrast, seven studies analyzed MetS according to the IDF criteria, comprising a sample of 2,168 people.[25,27,29-32,35]

In order to understand such differences between the studies, meta-analyses were performed using study type and division of geographic region by continent as moderators, with only the analysis by continent proving useful. As illustrated in Figure 4.a, the meta-analysis of the prevalence of MetS (NCEP ATP III) in infarcted patients revealed that the African continent exhibited the highest pooled prevalence estimate, at 0.61 [95% CI: 0.58; 0.63]. The studies demonstrated low heterogeneity ($I^2 = 0.0\%$) and p = 0.9938, which was anticipated given that the four studies were authored by the same researcher.[29–32]

With regard to the prevalence of MetS in the Asian and American continents, subtle differences were analyzed. In the former population, the estimated prevalence was 0.55 [95% CI: 0.46; 0.64], with moderate heterogeneity (I2=41.6%, p= 0.1632). For the population of the Americas, the prevalence was 0.43 [95% CI: 0.37; 0.49], with substantial heterogeneity observed (I2=41.6%, p= 0.1632). A higher prevalence of MetS has been observed among patients with myocardial infarction in Asia. However, this data must be analyzed with caution, considering the heterogeneity and variability between studies. In the subgroup analysis, a prevalence that varied significantly between the groups was evidenced, with the groups being better evaluated separately ($X^2_3 = 44.57$ and $p < 0.0001$).

Moreover, a prevalence meta-analysis was conducted, incorporating the IDF MetS criteria (Fig. 4.b), the continent with the highest and lowest combined prevalence estimates, respectively, was the Americas with 0.84 [95% CI: 0.71; 0.92] and Asia with 0.42 [95% CI: 0.16; 0.73]. However, the initial group comprised a single study, and the Asian study group exhibited substantial heterogeneity ($I^2 = 97.8\%$) and a p-value < 0.05. The subgroup analysis demonstrated a significant discrepancy between the three groups under evaluation, thereby underscoring the necessity for a tailored analysis for each group ($X^2_2 = 12.85$, p-value < 0.0016 for random effects). Furthermore, only one study classified MetS according to World Health Organization criteria.[36] This American study, which involved 553 subjects, revealed a prevalence of MetS that was found to be 0.61 [95% CI: 0.57; 0.65].

A meta-analysis of smoking prevalence in young patients who suffered AMI was finally performed. The present study is comprised of seven studies, which collectively analysed 1,127 patients.[24,27,33–35,37] The pooled prevalence estimate was 0.63 [95% CI: 0.51; 0.74], indicating a high predominance of smokers among young patients who suffered infarction. The heterogeneity between studies was found to be extremely significant (I2 = 94.3%), with a p-value of less than 0.0001.

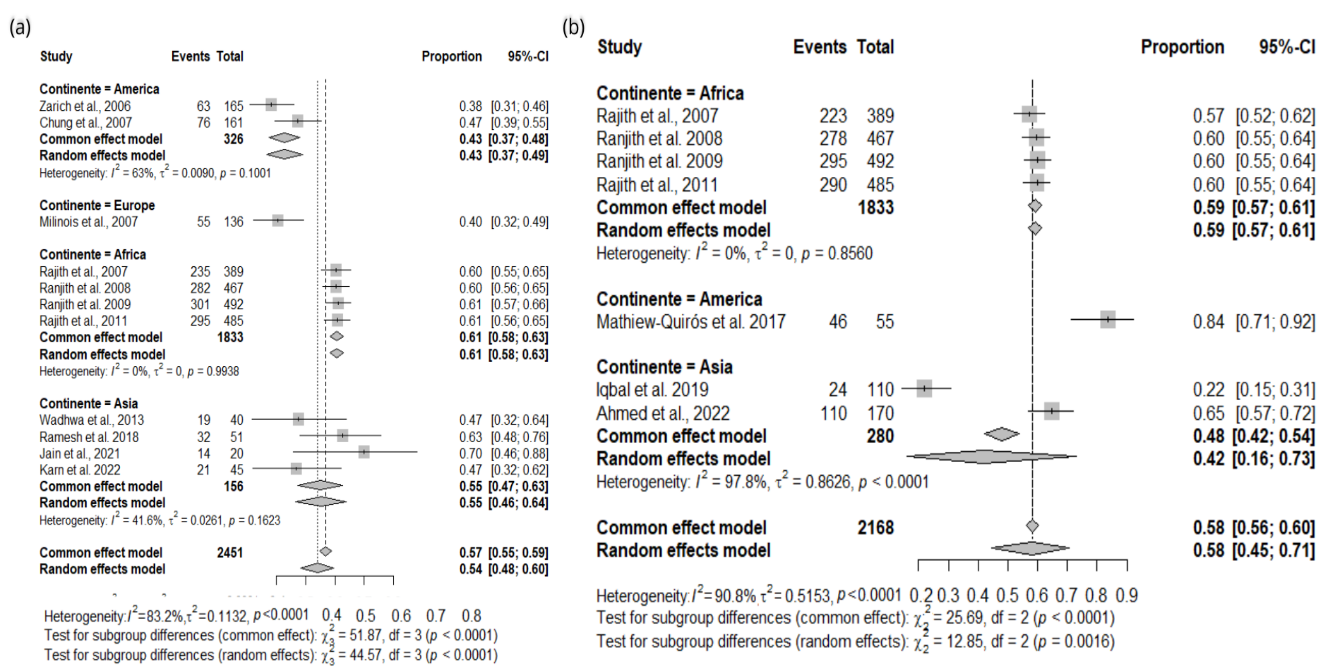

Figure 4a heterogeneity lines:
Heterogeneity: $I^2 = 63\%$, $\tau^2 = 0.0090$, $p = 0.1001$
Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.9938$
Heterogeneity: $I^2 = 41.6\%$, $\tau^2 = 0.0261$, $p = 0.1623$
Heterogeneity: $I^2 = 83.2\%$, $\tau^2 = 0.1132$, $p < 0.0001$
Test for subgroup differences (common effect): $\chi^2_3 = 51.87$, df = 3 ($p < 0.0001$)
Test for subgroup differences (random effects): $\chi^2_3 = 44.57$, df = 3 ($p < 0.0001$)

Figure 4b heterogeneity lines:
Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.8560$
Heterogeneity: $I^2 = 97.8\%$, $\tau^2 = 0.8626$, $p < 0.0001$
Heterogeneity: $I^2 = 90.8\%$, $\tau^2 = 0.5153$, $p < 0.0001$
Test for subgroup differences (common effect): $\chi^2_2 = 25.69$, df = 2 ($p < 0.0001$)
Test for subgroup differences (random effects): $\chi^2_2 = 12.85$, df = 2 ($p = 0.0016$)

Figure 4: Forest plots showing the prevalence of metabolic syndrome according to different criteria, stratified by continents. Panel (a) presents results using the NCEP ATP III criteria, while panel (b) shows results using the IDF criteria.

DISCUSSION

In this systematic review and meta-analysis, metabolic syndrome (MetS) was found to be consistently associated with a significantly increased risk of acute myocardial infarction (AMI). The combined odds ratio of the four eligible case-control studies indicated that young individuals with MetS were 296% more likely to develop AMI compared to those without the syndrome. The findings, when considered collectively, indicate that, in numerous clinical settings, a significant proportion of patients who experience myocardial infarction (MI) exhibit a constellation of cardiometabolic factors, which are associated with a fourfold increased risk of AMI.

The heterogeneity of the association meta-analysis was substantial (I^2 = 68%, p = 0.0248), indicating relevant differences between studies, possibly related to the incidence of the syndrome in the analysed populations. The study by Mathiew-Quirós et al.[35] is noteworthy, as 83.6% of patients with AMI met the criteria for MetS, resulting in an odds ratio of 11.42 (95% CI: 4.58–28.53). This value is considerably higher than those observed in other studies, whose odds ratios ranged from 2.21 (95% CI: 1.31–3.73) to 3.62 (95% CI: 1.34–9.77).

Subgroup analyses further underscore the significance of geographic variations in the magnitude of the problem. In studies that employed the NCEP ATP III criteria, the prevalence was observed to be highest in Africa (61%; 95% CI: 0.58–0.63), followed by Asia (55%; 95% CI: 0.46–0.64), America (46%; 95% CI: 0.37–0.49), and Europe (40%; 95% CI: 0.32–0.49). These findings corroborate previous results, such as those described by Pandey et al[39] in a cross-sectional hospital study conducted in Asia, which identified episodes of AMI in 75% of young patients diagnosed with MetS by NCEP ATP III.

Combining the studies that employed International Diabetes Federation (IDF) criteria, the prevalence of MetS in patients with AMI was 58% (95% CI: 0.49–0.67), a result analogous to the sole study that utilised World Health Organization (WHO) criteria, in which the prevalence was 61% (95% CI: 0.57–0.65). A convergent finding was described by Mente et al[8], who highlighted the association of MetS with a higher risk of AMI according to both the IDF (OR: 2.69; 95% CI: 2.45–2.95) and WHO (OR: 2.20; 95% CI: 2.03–2.38) criteria. In the analysis stratified by continent, the IDF reported that the prevalence was highest in the Americas (84%), followed by Africa (59%) and Asia (42%). These results will be discussed later by the authors.

The analysis by continent based on the IDF demonstrated significant heterogeneity (I^2 = 90.8%). The study by Mathiew-Quirós et al[35], cited above, was distinguished by a prevalence of 84%, while Iqbal et al[25] reported a significantly lower rate of 22%, thereby highlighting substantial disparities between populations. The dispersion of the Asian studies stands in marked contrast to the consistency of the African studies conducted by Ranjith et al.[29-32] which originated from the same hospital center, used uniform protocols, and overlapped periods. In these analyses, the estimated prevalence was virtually identical between the years evaluated, with 61% according to the NCEP ATP III and 60% according to the IDF, suggesting possible sample overlap and low statistical dispersion.

In a cross-sectional study conducted by Asato et al[40] that investigated the variation of MetS in Japanese, Caucasian, Filipino and Native Hawaiian populations; an investigation in Asian-American populations is mentioned, in which many individuals did not meet the cut-off values for obesity and other components required for diagnosis, resulting in a widespread underestimation of the metabolic burden syndrome in this population; in contrast to the previous statement, the IDF criteria identified that at least a quarter of adults in the United States have metabolic syndrome; finally, the authors also emphasize that the prevalence of MetS varies significantly with the diagnostic criteria of MetS applied based on the definitions established by different institutions.

In consideration of the preceding context, the findings of the present study demonstrate congruence with those of Wong et al[41], whose meta-analysis encompassing 13.2 million individuals exhibited a heightened prevalence of abdominal obesity in South America (55.1%; 95% CI: 45.8–64.3%) and Central America (52.9%; 95% CI: 32.7–72.7%), followed by Southern Europe (51.9%; 95% CI: 46.6–57.3), Africa (49.6%; 95% CI: 38.3–60.8%) and Western Asia (48.0%; 95% CI: 43.7–52.3%). In the present meta-analysis, the prevalence of MetS in patients with AMI, based on IDF, was higher in the Americas (84%), followed by Africa (59%), and Asia (42%), and no European study met the established inclusion criteria.[41] The observed similarity in the prevalence of MetS worldwide is noteworthy when compared to the results found for central obesity, evidencing a close relationship between both phenomena.

The prevalence of smoking was found to be a significant associative factor, with a high prevalence observed in patients with AMI (63%; 95% CI: 51–74%). These findings serve to reinforce the persistent role of tobacco as a determinant of cardiovascular morbidity and mortality, with an early impact on the course of the disease. A report published in 2020 by the World Health Organization (WHO), the World Heart Federation, and Newcastle University[42] demonstrates that smokers are more prone to experiencing a cardiovascular event at a younger age and at an earlier stage in the progression of their disease. Furthermore, 1.9 million preventable deaths per annum from coronary artery disease are recorded, with the cause attributed to tobacco use or passive exposure to the substance.

It is important to note that the lack of stratification by sex in the present study may introduce a significant bias in the meta-analysis, given that there is consistent evidence of significant heterogeneity between men and women in both the prevalence and expression of MetS components.[43] Similarly, other studies demonstrate sex-specific patterns that affect the metabolic profile, such as higher hypertriglyceridemia in men and a higher prevalence of low HDL-C and abdominal adiposity in women.[44] Another factor influencing estimates related to AMI and shaping the interpretation of results is the interaction of non-modifiable, modifiable, and psychosocial factors, such as sex, race, heredity, low socioeconomic status, stress, and depression, since the association among these determinants contributes to different epidemiological profiles across specific regions and continents.[45]

In summary, both the NCEP ATP III and IDF criteria revealed a high prevalence of MetS in patients with AMI, although marked differences were evident between continents, reflecting the influence of population, environmental, and methodological factors. However, it should be noted that the generalizability of the results was limited by the inclusion of only a small number of studies from specific continents, such as Europe and the Americas. Furthermore, the risk of bias assessment of the studies demonstrated that several studies were classified as serious or critical risk, particularly due to bias due to confounding factors, resulting from the lack of appropriate statistical analyses for confounding variables, particularly those related to potentiators of acute myocardial infarction. Consequently, the findings should be interpreted with caution; nevertheless, they consistently reinforce the association between MetS and a higher risk of AMI.

CONCLUSION

This systematic review and meta-analysis revealed a strong association between metabolic syndrome and acute myocardial infarction (AMI) in young adults, as well as a significant prevalence of metabolic syndrome in AMI patients. However, caution is essential when interpreting these results since the included studies are observational and predominantly have a high risk of bias accompanied by considerable heterogeneity. There is a clear need for studies with greater methodological rigor, especially prospective cohort studies in young populations that evaluate metabolic syndrome and its components, as well as stratifications by sex and ethnicity and their associations with AMI occurrence. Nevertheless, the findings of this study underscore the importance of being vigilant about this association, which is a significant public health concern. If confirmed, these results could inform more effective prevention strategies, as AMI in young adults is a significant clinical, social, and economic problem.

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REFERENCES

1. Wu WY, Berman AN, Biery DW, Blankstein R. Recent trends in acute myocardial infarction among the young. Curr Opin Cardiol. 2020; 35(5):524-30. DOI: 10.1097/HCO.0000000000000781.

2. Gulati R, Behfar A, Narula J, Kanwar A, Lerman A, Cooper L, et al. Acute myocardial infarction in young individuals. Mayo Clin Proc. 2020; 95(1):136-56. DOI: 10.1016/j.mayocp.2019.05.001.

3. Arora S, Stouffer GA, Kucharska-Newton AM, Qamar A, Vaduganathan M, Pandey A, et al. Twenty year trends and sex differences in young adults hospitalized with acute myocardial infarction. Circulation. 2019; 139(8):1047-56. DOI: 10.1161/CIRCULATIONAHA.118.037137.

4. Desai R, Mishra V, Chhina AK, Jain A, Vyas A, Allamneni R, et al. Cardiovascular disease risk factors and outcomes of acute myocardial infarction in young adults: evidence from two nationwide cohorts in the United States a decade apart. Curr Probl Cardiol. 2023; 101747. DOI: 10.1016/j.cpcardiol.2023.101747.

5. Krittanawong C, Khawaja M, Tamis□Holland JE, Girotra S, Rao SV. Acute myocardial infarction: etiologies and mimickers in young patients. J Am Heart Assoc. 2023; 12(18). DOI: 10.1161/JAHA.123.029971.

6. Dattoli-García CA, Jackson-Pedroza CN, Gallardo-Grajeda AL, Gopar-Nieto R, Araiza-Garaygordobil D, Arias-Mendoza A. Acute myocardial infarction: review on risk factors, etiologies, angiographic characteristics and outcomes in young patients. Arch Cardiol Mex (Engl Ed). 2022; 91(4). DOI: 10.24875/acm.20000386.

7. Dimitrova IN. Acute myocardial infarction in young individuals: demographic and risk factor profile, clinical features, angiographic findings and in-hospital outcome. Cureus. 2023. DOI: 10.7759/cureus.45803.

8. Mente A, Yusuf S, Islam S, McQueen MJ, Tanomsup S, Onen CL, et al. Metabolic syndrome and risk of acute myocardial infarction a case-control study of 26,903 subjects from 52 countries. J Am Coll Cardiol. 2010; 55(21):2390-8. DOI: 10.1016/j.jacc.2009.12.053.

9. Nguyen NT, Nguyen TN, Nguyen KM, Tran HPN, Huynh KLA, Hoang SV. Prevalence and impact of metabolic syndrome on

in-hospital outcomes in patients with acute myocardial infarction: a perspective from a developing country. Medicine (Baltimore). 2023; 102(45):e35924. DOI: 10.1097/MD.0000000000035924.

10. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. J Clin Epidemiol. 2021; 134:178-89. DOI: 10.1136/bmj.n71.

11. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. Syst Rev. 2016; 5(1). DOI: 10.1186/s13643-016-0384-4.

12. Higgins JPT, Savović J, Page MJ, Elbers RG, Sterne JAC. Assessing risk of bias in a randomized trial. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA, editors. Cochrane handbook for systematic reviews of interventions. 2nd ed. Chichester (UK): Wiley-Blackwell; 2019. p. 205-28. DOI: 10.1002/9781119536604.ch8.

13. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, et al. Cochrane handbook for systematic reviews of interventions. 2nd ed. Chichester (UK): Wiley; 2019. DOI: 10.1002/9781119536604.

14. R Core Team. R: a language and environment for statistical computing. Reference index. Vienna (Austria): R Foundation for Statistical Computing; 2025 [cited 2025 May 10]. Available from: https://cran.r-project.org/doc/manuals/r-release/fullrefman.pdf.

15. Schwarzer G, Carpenter JR, Rücker G. Meta-analysis with R. Cham: Springer; 2015. DOI: 10.1007/978-3-319-21416-0.

16. Stijnen T, Hamza TH, Ozdemir P. Random effects meta-analysis of event outcome in the framework of the generalized linear mixed model with applications in sparse data. Stat Med. 2010; 29(29):3046-67. DOI: 10.1002/sim.4040.

17. Viechtbauer W. Bias and efficiency of meta-analytic variance estimators in the random-effects model. J Educ Behav Stat. 2005; 30(3):261-93. DOI: 10.3102/10769986030003261.

18. Clopper CJ, Pearson ES. The use of confidence or fiducial limits illustrated in the case of the binomial. Biometrika. 1934; 26(4):404-13. DOI: 10.1093/biomet/26.4.404.

19. Deeks JJ, Higgins JPT, Altman DG, on behalf of the Cochrane Statistical Methods Group. Analysing data and undertaking meta-analyses. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA, editors. Cochrane handbook for systematic reviews of interventions. 2nd ed. Chichester (UK): Wiley; 2019. p. 241-84. DOI: 10.1002/9781119536604.ch10.

20. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003; 327(7414):557–60. DOI: 10.1136/bmj.327.7414.557.

21. Guyatt G, Oxman AD, Akl EA, Kunz R, Vist G, Brozek J, et al. GRADE guidelines: 1. Introduction-GRADE evidence profiles and summary of findings tables. J Clin Epidemiol. 2011; 64(4):383-94. DOI: 10.1016/j.jclinepi.2010.04.026.

22. Balshem H, Helfand M, Schünemann HJ, Oxman AD, Kunz R, Brozek J, et al. GRADE guidelines: 3. rating the quality of evidence. J Clin Epidemiol. 2011; 64(4):401-6. DOI: 10.1016/j.jclinepi.2010.07.015.

23. Wadhwa A, Avasthi R, Ghambhir JK, Dwivedi S. To study the prevalence and profile of metabolic syndrome, levels of hs-CRP, Lp(a) and serum ferritin in young Indian patients (≤45 years) with acute myocardial infarction. J Assoc Physicians India. 2013; [cited 2025 Jan. 30];61(6):384-6. Available from: https://pubmed.ncbi.nlm.nih.gov/24640203/.

24. Ramesh G, Sai NVB, Gururaj P, Bhupal R, Patel N. Association of metabolic syndrome and level of hs-CRP, Lp(a), and serum ferritin in young Asian patients (≤45 years) with acute myocardial infarction. Interv Med Appl Sci. 2018; 10(2):65-9. DOI: 10.1556/1646.10.2018.14.

25. Iqbal MU, Khalid MS, Ahmed S, Mumtaz I, Iqbal M, Kousar R. Frequency of metabolic syndrome in patients of acute ST segment elevation myocardial infarction. Med Forum. 2019 [cited 2025 Jan. 23]; 30(8):77-81. Available from: https://www.embase.com/records?id=L2004003510.

26. Jain R, Tomar RPS, Singh VK, Rastogi V, Rastogi R. Study of association between metabolic syndrome and acute myocardial infarction. J Int Med Sci Acad. 2021 [cited 2025 Feb. 02]; 34(1):34-8. Available from: https://www-embase-com.ez3.periodicos.capes.gov.br/records?id=L2013256221.

27. Ahmed R, Mal V, Ali A, Memon FL, Ahmed T, Shahab RS, et al. Prevalence of metabolic syndrome in young patients with acute ST elevation myocardial infarction (STEMI). Pak J Med Health Sci. 2022; 16(4):627-9. DOI: 10.53350/pjmhs22164627.

28. Karn JPL. A retrospective study on cardiovascular risk factors among acute coronary syndrome inpatients. Eur J Mol Clin Med. 2022 [cited 2025 Feb 04];9(4):1407-11. Available from: https://www-embase-com.ez3.periodicos.capes.gov.br/records?id=L2019657538.

29. Ranjith N, Pegoraro RJ, Naidoo DP, Esterhuizen TM. Metabolic syndrome in young Asian Indian patients with myocardial infarction. Cardiovasc J Afr. 2007 [cited 2025 Feb 14]; 18(4):228-33. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC4170226/.

30. Ranjith N, Pegoraro RJ, Naidoo DP, Shanmugam R, Rom L. Genetic variants associated with insulin resistance and metabolic syndrome in young Asian Indians with myocardial infarction. Metab Syndr Relat Disord. 2008; 6(3):209-14. DOI: 10.1089/met.2008.0023.

31. Ranjith N, Pegoraro RJ, Rom L. Lipid profiles and associated gene polymorphisms in young Asian Indian patients with acute myocardial infarction and the metabolic syndrome. Metab Syndr Relat Disord. 2009; 7(6):571-8. DOI: 10.1089/met.2009.0015.

32. Ranjith N, Pegoraro RJ, Shanmugam R. Obesity-associated genetic variants in young Asian Indians with the metabolic syndrome and myocardial infarction. Cardiovasc J Afr. 2011; 22:25-30. DOI: 10.5830/cvja-2010-036.

33. Zarich S, Luciano C, Hulford J, Abdullah A. Prevalence of metabolic syndrome in young patients with acute MI: does the Framingham Risk Score underestimate cardiovascular risk in this population? Vasc Dis Res. 2006; 3(2):103-7. DOI: 10.3132/dvdr.2006.012.

34. Chung EH, Curran PJ, Sivasankaran S, Chauhan MS, Gossman DE, Pyne CT, et al. Prevalence of metabolic syndrome in patients ≤45 years of age with acute myocardial infarction having percutaneous coronary intervention. Am J Cardiol. 2007; 100(7):1052-5. DOI: 10.1016/j.amjcard.2007.05.028.

35. Mathiew-Quirós Á, Salinas-Martínez AM, Guzmán de la Garza FJ, Garza-Sagástegui MG, Guzmán-Delgado NE, Palmero-Hinojosa MG, et al. Myocardial infarction in young Mexicans associated to metabolic syndrome. Gac Med Mex. 2017 [cited 2025 Feb 10];153(3):297-304. Available from: https://www.imbiomed.com.mx/articulo.php?id=110620.

36. Fernandes R, Forey KF. Cardiometabolic risk factors in young adults diagnosed with acute myocardial infarction. Eur J Prev Cardiol. 2023; 30(Suppl 1). DOI: 10.1093/eurjpc/zwad125.314.

37. Milionis HJ, Kalantzi KJ, Papathanasiou AJ, Kosovitsas AA, Doumas MT, Goudevenos JA. Metabolic syndrome and risk of acute coronary syndromes in patients younger than 45 years of age. Coron Artery Dis. 2007; 18(4):247-52. DOI: 10.1097/MCA.0b013e328035f8c4.

38. McGuinness LA, Higgins JPT. Risk-of-bias visualization (robvis): an R package and Shiny web app for visualizing risk-of-bias assessments. Res Synth Methods. 2020. DOI: 10.1002/jrsm.1411.

39. Pandey S, Baral N, Majhi S, Acharya P, Karki P, Shrestha S, et al. Prevalence of the metabolic syndrome in acute myocardial infarction and its impact on hospital outcomes. Int J Dev Ctries. 2009; 29(2):52. DOI: 10.4103/0973-3930.53120.

40. Asato CB, Nelson-Hurwitz DC, Lee T, Grandinetti A. Comparative analysis of metabolic syndrome diagnostic criteria and its effects on prevalence in a multiethnic population. Metab Syndr Relat Disord. 2021; 19(6):347-51. DOI: 10.1089/met.2020.0090.

41. Wong MCS, Huang J, Wang J, Chan PSF, Lok V, Chen X, et al. Global, regional and time-trend prevalence of central obesity: a systematic review and meta-analysis of 13.2 million subjects. Eur J Epidemiol. 2020; 35(7):673-83. DOI: 10.1007/s10654-020-00650-3.

42. Puig-Cotado F, Tursan d'Espaignet E, St Claire S, Bianco E, Bhatti L, Schotte K, et al. Tobacco and coronary heart disease. WHO tobacco knowledge summaries. Geneva: World Health Organization; 2020 Sep. [cited 2025 Aug. 15] Available from: https://www.drugsandalcohol.ie/33060/.

43. Chackrewarthy S, Gunasekera D, Pathmeswaren A, Wijekoon CN, Ranawaka UK, Kato N, et al. A comparison between revised NCEP ATP III and IDF definitions in diagnosing metabolic syndrome in an urban Sri Lankan population: the Ragama Health Study. ISRN Endocrinol. 2013: 320176. DOI: 10.1155/2013/320176.

44. Becerra Leal AV, Torres A, Valery L, Arata-Bellabarba G, Velázquez-Maldonado EM. Prevalencia del síndrome metabólico en la población urbana de Mucuchíes, Mérida-Venezuela. Rev Venez Endocrinol Metab.2009 [cited 2026 Apr 10]; 7(3):16-22. Available from: https://ve.scielo.org/scielo.php?pid=S1690-31102009000300004&script=sci_arttext.

45. Lunkes LC, Murgas LDS, Dorneles EMS, Rocha CBM, Machado GJ. Fatores socioeconômicos relacionados às doenças cardiovasculares: uma revisão. Hygeia Rev Bras Geogr Med Saude. 2018. DOI: 10.14393/Hygeia142804.