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Metabolic Syndrome: An Updated Review on Diagnosis and Treatment for Primary Care Clinicians

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Abstract

Objective: Metabolic syndrome is a cluster of cardiovascular risk factors (central obesity, hypertension, dyslipidemia, and insulin resistance) that affects between 12.5% and 31.4% of adults worldwide. It correlates with increased risks of cardiovascular disease, diabetes, cancer, and overall mortality in a dose-dependent fashion. This review aims to provide primary care clinicians an updated review of the evidence on metabolic syndrome, with a focus on treatment. **Design:** Scoping evidence review. **Eligibility Criteria:** English-language studies of evidence Level I or II that focused on defining, diagnosing, and treating metabolic syndrome or its components. **Information Sources:** PubMed and Cochrane Database of Systematic Reviews. **Results:** Though evidence is still lacking for improved outcomes with treating the syndrome per se, addressing its individual components reduces risks. Lifestyle changes like weight loss and increased physical activity are first line. Surgical options assist with weight loss for certain patients. Pharmacotherapies like glucagon-like peptide-1 receptor agonists, sodium-glucose cotransporter-2 inhibitors, statins, and antihypertensives also have efficacy. **Conclusions:** Metabolic syndrome is an independent risk factor for many poor health outcomes. Its individual components should be treated with medication and behavioral changes to reduce cardiovascular risk and prevent diabetes and its complications. More research is needed on how to treat the syndrome itself. A diagnosis of metabolic syndrome may be useful for motivating patients toward lifestyle changes, though more research is needed on how to treat the syndrome versus its components.

Keywords

metabolic syndrome, preventive medicine, risk reduction behavior, chronic disease

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Key Points

What is already known on this topic?

This research is focused on providing an updated review of the evidence on metabolic syndrome for primary care clinicians by exploring the diagnosis and treatment options for metabolic syndrome.

What this study adds?

Treating individual components of metabolic syndrome can reduce atherosclerotic cardiovascular disease risk while treatment of the syndrome as a whole has unclear outcomes. Intensive lifestyle change based behavioral interventions are effective for ≥5% weight loss and diabetes prevention aspects of metabolic syndrome management (SORT level B). Medications and surgeries are effective for weight loss ≥5% to 20% and diabetes prevention in patients with metabolic syndrome (SORT Level B).

How this study might affect research, practice, or policy?

This research may help improve the management of patients with metabolic syndrome in primary care settings.

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Introduction

Metabolic syndrome is a group of health conditions that occur together and increase the risk of developing serious health problems. Global metabolic syndrome prevalence ranges from 12.5% to 31.4%.[1] One in 20 adolescents worldwide had metabolic syndrome in 2020, as well as about 3% of children[2]; it is more common in the US ($34.5 \pm 0.9\%$)[3] and Canada (19.1%).[4] Metabolic syndrome correlates with cardiovascular disease (CVD), nonalcoholic fatty liver disease (NAFLD), inflammation, cancer risks, chronic kidney disease (CKD), dyslipidemia, type 2 diabetes (T2DM) and insulin resistance, childhood obesity, and overall mortality. However, primary care providers can treat this syndrome with a combination of effective behavioral techniques, growing medical management options, and surgical interventions.

Primary care clinicians frequently manage patients with risk factors and/or a diagnosis of metabolic syndrome. This article offers an updated review of the evidence about the prevalence, pathophysiology, associated conditions, assessment tools, and treatment of metabolic syndrome.

Methods

The prevalence of metabolic syndrome makes it a frequently studied condition, so high-level evidence was available for review. A total of 340 articles found through searches of the PubMed and Cochrane databases were reviewed by the authors May to September 2023. Keywords included metabolic syndrome, MetS, ASCVD, blood pressure, lipid, Homa-IR, Waist circumference, A1c, and their equivalents/abbreviations/pluralities. Date range of articles was 2002 to 2023. These 2 databases were chosen for their broad reaching scope, and no others were included due to time limitations of the team. The title and abstract screening was performed by 1 author. A total of 69 articles were excluded based on abstract being irrelevant. A detailed annotated bibliography was performed for 271 articles with abstracts in Microsoft Word. There were 2 articles on A1c and MetS, 2 on ASCVD and MetS, 60 on Blood pressure and MetS, 212 on lipids and MetS, 49 on Homa-IR and Mets (or 30 on fasting glucose and Met S), and 15 on Waist circumference (or BMI) and Met S. No efforts were able to be made to pursue acquiring the 31 articles for which the team did not have access. About 72 English-language studies with Level I or Level II quality of evidence underwent full text review by 1 author, with 2 authors reviewing. No interrater review calculations were performed, but the authors all agreed on the final annotated bibliography and which articles to include in drafts. The reasons that articles were excluded were lack of Level I-II evidence, inability to access the full study, irrelevance to this study, or lack of space in final document (definitions, pathophysiology, assessment tools were excluded post-hoc during revision process to focus on clinically relevant treatment data). Data items included primary outcomes: metabolic syndrome risk factors, diagnosis, and treatment. The focus of the review was narrowed to metabolic syndrome treatment to accommodate the 50-citation limit for this journal. Studies only describing the definitions and studies focused on a specific risk factor without assessing treatment were subsequently excluded (n = 22, Table 1; Figure 1). Although there was no age cut off for studies' inclusion, the final draft focused on adult metabolic syndrome, excepting a few pediatric studies that focus on projecting future adult metabolic syndrome. A narrative synthesis approach was used to compare effects with various measures reported, including odds ratios, hazard ratios, and risk ratios. This review was not registered, nor was it a protocol published previously. This study was not funded.

Results

Defining Metabolic Syndrome

The 5 main components of metabolic syndrome are abdominal/central obesity, high blood pressure, impaired glucose metabolism (high blood sugar), and triglyceride dysfunction (elevated levels of triglycerides, low levels of high-density lipoprotein cholesterol [HDL-C]), with or without renal dysfunction. A person is diagnosed with metabolic syndrome if they have 3 of these 5 components, depending on which definition is used.[3]

The Importance of Treating Metabolic Syndrome

There remains a lack of evidence to show improved patient related outcomes with treatment of the syndrome as a whole. However, there is substantial evidence to report on both disease related outcomes and patient related outcomes for treatment of the syndrome's individual components. The primary clinical outcome with the biggest impact is ASCVD risk reduction. (Table 2).

1. Cardiovascular disease (CVD): CVD, including stroke and myocardial infarction (MI), are tangible outcomes that many patients and their families experience. Metabolic syndrome *z* score is a tool that can help predict CVD, 25-year coronary heart disease (CHD), and all-cause mortality.[5,7,8]

2. Diabetes: The Princeton Lipid Research cohort study found that elevated insulin levels and metabolic syndrome *z* score in adults were each independently associated with increased likelihood of developing diabetes and CVD in the subsequent 11.2 years.[10] An increase of 1 unit in the logarithm of insulin was associated with an

Table 1. Studies of Risk Factors Associated With Metabolic Syndrome.

Risk factor	Study design	Hazard ratio (95% CI)
Cardiovascular disease	Comparing subjects with >75th percentile metabolic syndrome z score vs those <25th percentile metabolic syndrome z score, 2006-2018[5]	2.05 (1.86-2.25)
Atherosclerotic cardiovascular disease	Risk in men vs women in the period of 7 years follow-up, using structural equation modeling scoring system of metabolic syndrome[6]	Men: 1.39 (1.15-1.67) Women: 1.31 (1.12-1.52)
Coronary heart disease	25-year risk of atherosclerosis among Black and White adults aged 45-64 years with or without diabetes[7]	1.64 (1.49-1.80)
All-cause mortality	Comparing subjects with metabolic syndrome z score >75th percentile vs those <25th percentile[8]	1.45 (1.35-1.56)
Myocardial infarction	Over 4 years 2010-2013, for a metabolic syndrome component exposure score, (range: 0-20) of 20 vs 0[8]	5.27 (4.20-6.62)
Stroke	Over 4 years 2010-2013, for a metabolic syndrome component exposure score, (range: 0-20) of 20 vs 0[8]	3.90 (3.09-4.93)
90-day recurrent stroke	Patients with metabolic syndrome (using IDF diagnosis criteria) and diabetes[9]	2.53 (1.89-3.37)

Abbreviations: CI, confidence interval; IDF, International Diabetes Foundation.

8-fold higher likelihood of developing T2DM ($P < .001$), and a 3-fold higher likelihood of developing CVD ($P < .001$).[10] The metabolic syndrome *z* score showed a significant association with both future T2DM and CVD, with OR of 5.6 ($P < .001$) and 3.5 ($P < .001$), respectively.[10]

3. Associated Conditions: Metabolic syndrome correlated with several other health conditions beyond CVD and T2DM, including NAFLD, CKD, cancers, and cognitive decline, as well as several markers of systemic inflammation.

4. Childhood Metabolic Syndrome: The severity of metabolic syndrome in childhood (ages 6-19, mean = 12.9 years) is associated with the incidence of adult T2DM, and the degree of increase in this severity predicts future T2DM, according to the Princeton Lipid Research Cohort Study.[11] The risk for childhood metabolic syndrome or any of its components is higher for those with the following characteristics: male, parental obesity (especially paternal), low body mass at birth, and omitting breakfast or dinner.[12] It is critical to prevent metabolic syndrome in families before children reach adulthood. For each unit increase in childhood metabolic syndrome *z* score, the OR of developing T2DM was 2.7 and 2.8 by age 38.5 and 49.6 years, respectively.[11] When examining the change of metabolic syndrome *z* score from childhood to mid-adulthood, developing T2DM by age 49.6 years became 7.3 times more likely with every 1-unit increase in metabolic syndrome *z* score.[11] Also, metabolic syndrome has an interplay with adolescents' menstrual cycles; polycystic ovarian syndrome has been shown to be an independent risk factor for metabolic syndrome in adolescents.[13]

Treatment of Metabolic Syndrome

A combination of pharmacologic options; a plant-based, whole foods diet; and exercise can decrease the severity of metabolic syndrome components, hence, reducing the risk of morbidity and mortality associated with metabolic syndrome.

Therapeutic lifestyle changes. In children, a weight-maintenance approach during growth with a focus on healthy habits is generally preferred as opposed to weight loss as a goal. Address the 5210 model (5 daily fruits/vegetables, <2 h screen time, 1 h exercise, and 0 sodas) at well-child checks, and ask whether the child's parents encourage regular family movement activities.[22] The 5210 model has been validated and shown to increase children's fruit and vegetable intake from 18% to 23% ($P < .001$) over 4 years.[22]

In adults, enacting changes toward a healthier lifestyle and a weight loss of 5% to 10% of initial body weight are generally recommended to treat metabolic syndrome. Lifestyle changes including moderate/vigorous physical activity are necessary for treating metabolic syndrome and its components and are more effective than metformin or placebo, but the question of how to effect these changes remains complex and the subject of public health research.[23-26]

In the primary care setting, behavioral weight loss interventions in groups such as the US National Diabetes Prevention Program have been shown to be superior to self-directed weight loss for patients with metabolic syndrome.[27] Quarterly primary care visits for lifestyle counselling for patients with 2 or more metabolic syndrome components over 2 years showed at least a 5% weight loss for about 21%

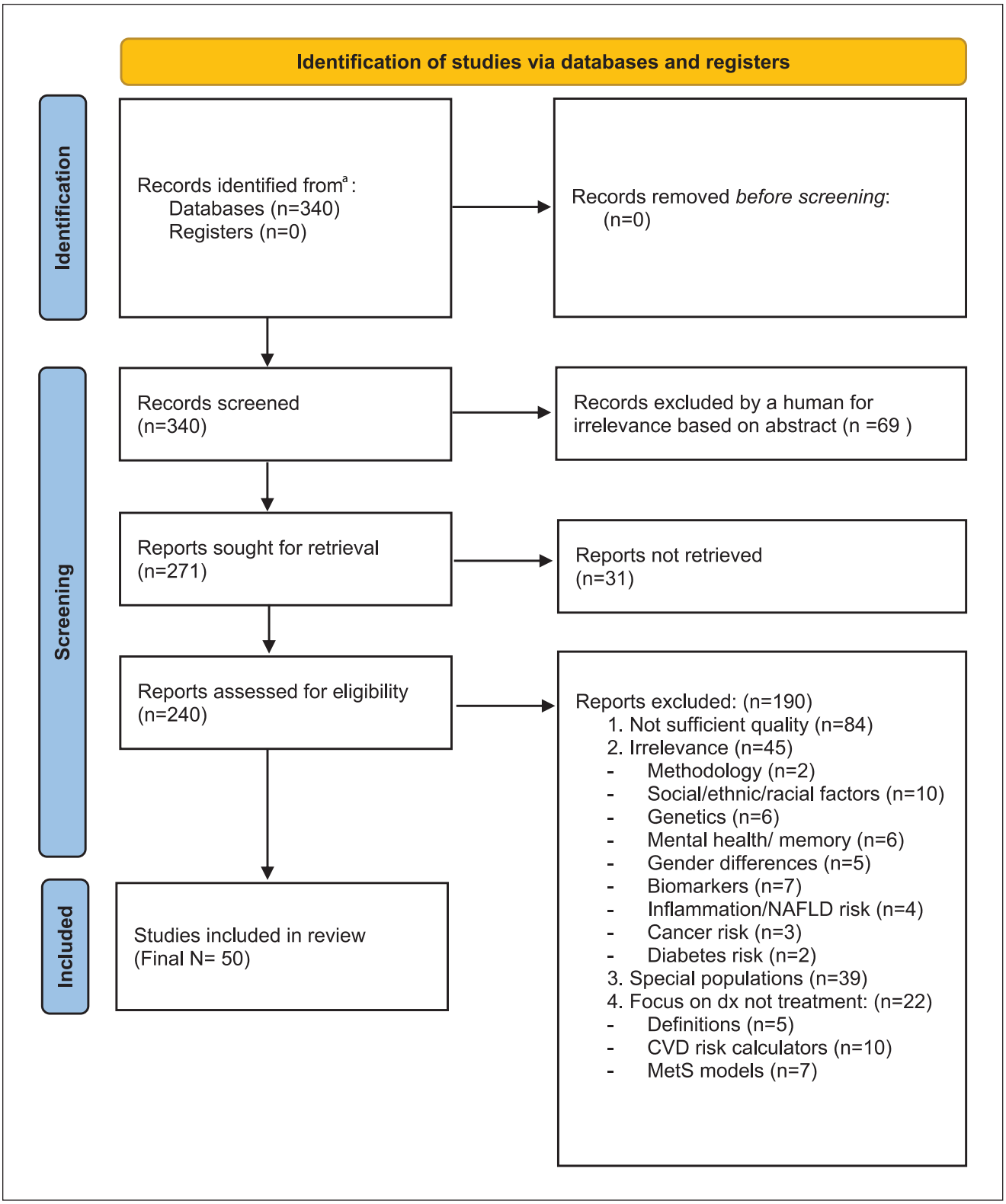

Figure 1. PRISMA flow diagram.
[a]Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).
Source: Page MJ, et al. BMJ 2021;372:n71. doi: 10.1136/bmj.n71.

Table 2. Comparison of Interventions for Metabolic Syndrome, by Component Diagnoses.

Diagnosis	Comparison (N)	Outcome measures	Treatment group (n)	Tx group outcomes	Control group (n)	Control group outcomes	Effect size (NNT)
Metabolic syndrome	Dapagliflozin or Dapagliflozin + metformin vs metformin alone (N = 248)[14]	Patients n (%) with remitting metabolic syndrome	Dapagliflozin (n = 89) Dapagliflozin + metformin (n = 77)	41 (46.1%) 59 (76.6%)	Metformin alone (n = 82)	47 (57.3%)	5
T2DM	Oral semaglutide vs subq semaglutide vs placebo (N = 632)[15]	HbA_{1C} <7.0% Proportion of patients achieving ≥5% WL	Oral semaglutide, 5 dosage groups 2.5 mg-40mg (n = 491)	HbA_{1C} goal: 2.5 mg = 44% 5 mg = 81% 10 mg = 84% 20 mg = 86% 40 mg = 90% WL goal: 2.5 mg N/A 5 mg N/A 10 mg = 56% 20 mg = 64% 40 mg = 71%	Subq semaglutide (n = 70) Placebo (n = 71)	HbA_{1C} goal: 93% WL goal: 66% HbA_{1C} goal: 28% WL goal: 13%	HbA_{1C} <7.0% 5 mg oral semaglutide: 2 Subq semaglutide: 2 ≥5% WL 40 mg oral semaglutide: 2 Subq semaglutide: 2
Overweight or obesity w/T2DM	Naltrexone SR + bupropion SR vs placebo (N = 505)[16]	Proportion of patients achieving ≥5% WL	Naltrexone SR/360 mg bupropion SR + lifestyle intervention (n = 335)	44.5%	Placebo + lifestyle intervention (n = 170)	18.9%	4
T2DM and metabolic syndrome	Fenofibrate + statin therapy vs statin only (N = 65 586)[17]	Diabetic retinopathy incidence per 1000 person-years	Fenofibrate + statin therapy (n = 22,395)	8.68	Statin-only (n = 43,191)	9.66	1030
Obesity w/T2DM	Bariatric surgery vs medical management (N = 316)[18]	HbA_{1C} <6.5% w/o medication	Laparoscopic sleeve gastrectomy w/ or w/o duodenojejunal bypass (n = 78)	56%; 75.6% w/ HbA_{1C} <7.0%	Medical treatment (n = 238)	0.4%; 29.0% w/ HbA_{1C} <7.0%	2
Overweight or obesity w/o T2DM	Semaglutide vs Liraglutide vs placebo (N = 338)[19]	Proportion of patients achieving ≥10% WL	Semaglutide 2.4 mg subq (n = 117)	70.9%	Liraglutide 3.0 mg subq (n = 127) Placebo (n = 85)	25.6% 15.4%	2
Obesity w/o T2DM	Liraglutide vs placebo (N = 3731)[20]	Proportion of patients achieving ≥5% WL	Liraglutide (3 mg subq) + lifestyle counseling (n = 2487)	63.2% achieved WL goal; 33.1% achieved >10% WL	Placebo + lifestyle counseling (n = 1244)	27.1% achieved WL goal; 10.6% achieved >10% WL	5% WL: 3 10% WL: 4
Obesity	Phentermine + topiramate (PHEN/TPM) 3.75/23 mg or PHEN/TPM 15/92 mg vs placebo (N = 1267)[21]	Proportion of patients achieving 5% WL	PHEN/TPM 3.75/23 mg (n = 241) PHEN/TPM 15/92 mg (n = 512)	44.9% 66.7%	Placebo (n = 514)	17.3%	2

Abbreviations: SR, sustained release; Subq, subcutaneous; T2DM, Type 2 diabetes mellitus; Tx, treatment; Vs, versus; w/, with; WL, weight loss; w/o, without.

of patients.[28] Items such as weight goals, weight history, and risk factors of metabolic syndrome may be useful topics for lifestyle discussion. Telehealth weight loss interventions are beginning to be explored for patients with metabolic syndrome as well.[29]

Any sustained behavior change that involves increased physical activity may be helpful to treat metabolic syndrome. Exercise programs ranging from moderate continuous and high-intensity interval training to yoga and Tai Chi can improve metabolic profiles and reduce metabolic syndrome severity.[30-33]

Adherence to specific diets, such as the Mediterranean-type diet, Dietary Approaches to Stop Hypertension (DASH) diet, and diets low in processed and inflammatory foods and high in lean fish and colorful vegetables, also can improve metabolic profiles and reduce the risk of metabolic syndrome.[34-44] The Mediterranean diet has been shown to lower overall and cardiovascular mortality for patients with metabolic syndrome.[45]

Pharmacotherapy. There are multiple pharmacologic options with evidence of improving metabolic syndrome components.

Only 27% of people who followed diet and exercise alone were able to lose 5% of body weight. However, semaglutide (number needed to treat [NNT] = 2) and liraglutide (NNT = 4) can help people lose at least 10% body weight loss in conjunction with diet and exercise and help achieve HbA_{1C} <7%.[15,19] Phentermine combined with topiramate (NNT = 2) supports 5% weight loss and decreasing HbA_{1C}.[21] Naltrexone combined with bupropion demonstrates 5% weight loss (NNT = 4) when compared with placebo.[16] Metabolic syndrome remission was shown with dapagliflozin plus metformin as compared with metformin alone (NNT = 5).[14] In addition, appropriate use of statins, antihypertensives (eg, angiotensin-converting enzyme inhibitors [ACEIs]), medications for lowering glucose (eg, glucagon-like peptide-1 receptor agonists [GLP1s], metformin, sodium-glucose cotransporter-2 inhibitors) can treat components of metabolic syndrome, including diabetes, hypertension, dyslipidemia, and complications of metabolic syndrome such as fatty liver disease.[17]

Weight loss options according to the most recent United States Preventive Service Task Force (USPSTF) systematic review[46] include GLP1s (eg, liraglutide and semaglutide), combination naltrexone and bupropion, orlistat, and combination phentermine and topiramate. GLP1s have directly been shown to decrease the severity of metabolic syndrome itself, primarily through weight loss.[15,19,21,47] Taking liraglutide for 13 months also has been shown to be associated with lower risk of incident diabetes.[20]

Surgical options have been shown to be more effective for weight loss than medical management in certain patients.[18] (Table 2) Bariatric surgeries can be recommended in patients with body mass index (BMI) >35 kg/m^2 or those with a BMI >30 kg/m^2 and a weight-related comorbidity.[48]

Conclusion

Fifteen years after a landmark review of metabolic syndrome,[49] there is still a lack of evidence to show improved patient-related outcomes with treatment of the metabolic syndrome as opposed to its respective components (Table 3). Metabolic syndrome is still an independent risk factor for many poor health outcomes including all-cause mortality, MI, stroke, CVD, CKD, CHD, heart failure, NAFLD, T2DM, cervical cancer, colorectal cancer, and esophageal cancer. Patients should be counselled on these risks as incentive to commit to treatment of metabolic syndrome.[50] Many studies recommend prevention and treatment for metabolic syndrome components through a combination of medication, surgery, and behavioral interventions including diet and exercise. Treating individual components of metabolic syndrome can reduce overall ASCVD risk, prevent diabetes and its complications, and facilitate significant weight loss. More research is needed to compare treatment of metabolic syndrome as a whole versus the sum of its parts and to further system-level changes that facilitate and incentivize healthier lifestyles for families.

Table 3. Metabolic Syndrome Scoping Review References.

Authors	Year	Countries	Target population	Sample size[a]	Sex/age distribution[b]
Noubiap et al.	2022	Global	General adult population	663 studies 28 193 768	18 years or older
Noubiap et al.	2022	Global	Children and adolescents	169 studies 550 405	0%-64.9%M; Median/mean age 7-18 years
Ford ES	2005	U.S.	Adults	3601	1776F (49.3%); Age range 20-70 years—evenly distributed
Riediger & Clara	2011	Canada	Adults	1800	representative sample aged 18-79 years
Chen et al.	2017	U.S.	Minor ischemic stroke/TIA patients with metabolic syndrome/diabetes	3044	1017F (33.4%); Median age 62.2 years (IQR 54.7-71.2)
DeBoer et al.	2017	U.S.	NHANES (1999-2010), a complex, multistage probability sample of the US population + Jackson Heart Study (JHS) participants were African American men and women	13 141	64%F; Mean age 53.8 years (ARIC), 48.5 years (JHS)
Kakadiaris et al.	2018	U.S.	MESA (the Multi-Ethnic Study of Atherosclerosis) study; participants who were atherosclerotic CVD-free at baseline	6459	Men and women 45-84 years
DeBoer et al.	2020	U.S.	ARiC study participants	8555	44%M; Mean age 53.8 years (5.6)
Viitasalo et al.	2014	Finland	Children and adults	3560	491 children, 1900 middle-aged men, 614 older women and 555 older men
DeBoer et al.	2016	U.S.	Princeton Lipid Research Cohort	711	Mean age 39.5 years
DeBoer et al.	2015	U.S.	Cincinnati Clinic of the National Heart Lung and Blood Institute Lipid Research Clinic (LRC) Prevalence Program Princeton Follow-up Study (PFS, 1998-2003)	629	43.7%M; Mean age 12.9 years (3.3)
Jankowska et al.	2021	Poland	Obese children	591	46.5%F; Age range 10-12 years
Fu et al.	2023	Global	Adolescents with PCOS	12 studies included	Age range 10-20 years
Rogers et al.	2013	U.S.	Parents who had children under 18 years living at home	800	67%F; 50% under 45 years; Children mean age 11.3 years (4.7)
Marseglia et al.	2021	Sweden	Gothenburg H70 Birth Cohort Study-Birth cohort—70-year-old adults without dementia	1131	53.3%F; Age 70 year
DeBoer et al.	2018	U.S.	Prediabetics	2476	31.1%M; 14.5% <45 years, 35.4% 45-49 years, 30.5% 50-59 years, 21.7% >60 years
Carson et al.	2019	U.S.	Resident civilian noninstitutionalized United States population	2544	48.9%F; Median age 11.2 years (IQR 8.1-14.1)
Thabit et al.	2013	Ireland	Construction workers Health Trust screening study	983	100%M; Mean age 36.3 years (10.5)
Ma et al.	2013	U.S.	Overweight or obese adults who are primary care patients	241	47%F; Mean age 52.9 years (10.6)
Wadden et al.	2011	U.S.	Obese primary care practice patients 21 years +	390	79.7%F; Mean age 51.5 years (11.5)
Luley et al.	2014	Germany	Patients with metabolic syndrome	70	57%F intervention, 46%F control; Mean age 57 years (9) intervention, 58 years (7) control
Heiston et al.	2020	U.S.	Overweight or obese adults with prediabetes	28	50%F; Mean age 60.9 years (8.4)
Peyer et al.	2017	U.S.	Obese individuals in the Ames	72	60.2%F; Mean age 38.6 years (14.6)

(continued)

Table 3. (continued)

Authors	Year	Countries	Target population	Sample size[a]	Sex/age distribution[b]
Mendoza-Núñez et al.	2018	Mexico	Older adults with metabolic syndrome	110	Mean age 68.2 years (6.6) control, 67.4 years (4.7) intervention
Lau et al.	2015	Hong Kong	Chinese adults with/without metabolic syndrome	173	60.9%F control, 65.1%F yoga; Mean age 52.0 years (7.4)
Grosso et al.	2015	Poland	Urban Polish adults	8821	51.4%F; Age range 45-69 years
Ren et al.	2018	China	Urban Chinese adults	1712	66%F; Mean age 50.4 years (17.4)
Ghorabi et al.	2020	Iran	Adults 18 years and older	404	37.6%F; Mean age 38.2 years (9.6)
Tørris et al.	2017	Norway	Norwegian Tromsø Study 4 and 6 participants, age 26-69 years	23 907	48%M; Mean age 44.1 years (11.5)
Farhadnejad et al.	2021	Iran	Iranian adults Tehran Lipid and Glucose Study	1625	45.8%M; Mean age 37.5 years (13.4)
Bian et al.	2013	China	Chinese adults	258	41.8%F; Mean age 54.0 years (10.4) case, 53.7 years (9.7) control
van der Haar et al.	2021	Netherlands	Motivated individuals at risk of MetS age ≥40 years	37	74%F; Mean age 61 years (8.2)
Mohammadpour et al.	2020	Iranian	Iranian adults, 18-75 years old	836	69%F; Mean age 47.7 years (10.7)
Lin et al.	2018	Taiwan	Taiwanese adults aged 20-64 years	212	48.5%M; Mean age 41.9 years (12.5)
Konieczna et al.	2022	Spain	Older adults with metabolic syndrome from PREDIMED-Plus trial	5867	47.8%F; Mean age 65.0 years (4.9)
Koochakpoor et al.	2016	Iran	Adults aged ≥18 years	1158	Mean age 43 years (12)
Fan et al.	2023	U.S.	NHANES 2007-2018 participants with metabolic syndrome per IDF	8301	55.1%F; Median age 56.7 years (95% CI 56.2-57.3)
Cheng et al.	2021	China	Patients with metabolic syndrome	248	52.8%M; Mean age 52 years
Davies et al.	2017	U.S.	Patients with type 2 diabetes	632	62.7%M; Mean age 57.1 years (10.6)
Hollander et al.	2013	U.S.	Overweight/obese patients with type 2 diabetes	505	54%F; Mean age 54 years
Kim et al.	2023	Korea	Patients with type 2 diabetes and metabolic syndrome (≥ 30 years)	65 586	Mean age 55.0 years
Seki et al.	2022	Japan	Mildly obese patients with type 2 diabetes	316	85%M; Mean age 47.7 years (9.9) surgery, 50.7 years (7.0) medical
Rubino et al.	2022	U.S.	Adults with overweight/obesity without diabetes	338	78.4%F; Mean age 49 years (13)
Pi-Sunyer et al.	2015	U.S.	Adults with overweight with comorbidities or obesity without DM2	3731	78.5%F; Mean age 45.1 years (12.0)
Allison et al.	2012	U.S.	Adults with class II or III obesity	1267	83%F; Mean age 42.7 years
LeBlanc et al.	2018	Global	Adults undergoing weight loss via behavioral change	122 RCTs with 62 533 participants + 2 observational studies with 209 993 participants	variable
Sandsdal et al.	2023	Denmark	Adults 18-65 years of age living with obesity, without diabetes or serious illness	195	63%F; Mean age 42 years (12)
Eisenberg et al.	2023	U.S.	n/a	n/a	n/a
Kahn et al.	2005	Global	n/a	n/a	n/a
Lin et al.	2014		Persons with cardiovascular risk factors	74 included studies	variable

[a]Participants unless otherwise specified.
[b]if available.

Authors' Note

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Availability of Data

Contact the authors for data used for analyses.

References

1. Noubiap JJ, Nansseu JR, Lontchi-Yimagou E, et al. Geographic distribution of metabolic syndrome and its components in the general adult population: a meta-analysis of global data from 28 million individuals. *Diabetes Res Clin Pract*. 2022;188:109924. doi:10.1016/j.diabres.2022.109924
2. Noubiap JJ, Nansseu JR, Lontchi-Yimagou E, et al. Global, regional, and country estimates of metabolic syndrome burden in children and adolescents in 2020: a systematic review and modeling analysis. *Lancet Child Adolesc Health*. 2022;6:158-170. doi:10.1016/S2352-4642(21)00374-6
3. Ford ES. Prevalence of the metabolic syndrome defined by the International Diabetes Federation among adults in the U.S. *Diabetes Care*. 2005;28:2745-2749. doi:10.2337/diacare.28.11.2745
4. Riediger ND, Clara I. Prevalence of metabolic syndrome in the Canadian adult population. *CMAJ*. 2011;183:E1127-E1134. doi:10.1503/cmaj.110070
5. Chen W, Pan Y, Jing J, et al. Recurrent stroke in minor ischemic stroke or transient ischemic attack with metabolic syndrome and/or diabetes mellitus. *J Amer Heart Assoc*. 2017;6:e005446. doi:10.1161/JAHA.116.005446
6. DeBoer MD, Gurka MJ, Golden SH, et al. Independent associations between metabolic syndrome severity and future coronary heart disease by sex and race. *JACC*. 2017;69:1204-1205. doi:10.1016/j.jacc.2016.10.088
7. Kakadiaris IA, Vrigkas M, Yen AA, et al. Machine learning outperforms ACC/AHA CVD risk calculator in MESA. *J Amer Heart Assoc*. 2018;7:e009476. doi:10.1161/JAHA.118.009476
8. DeBoer MD, Filipp SL, Gurka MJ. Associations of a metabolic syndrome severity score with coronary heart disease and diabetes in fasting vs. non-fasting individuals. *Nutr Metab Cardiovasc Dis*. 2020;30:92-98. doi:10.1016/j.numecd.2019.08.010
9. Viitasalo A, Lakka TA, Laaksonen DE, et al. Validation of metabolic syndrome score by confirmatory factor analysis in children and adults and prediction of cardiometabolic outcomes in adults. *Diabetologia*. 2014;57:940-949. doi:10.1007/s00125-014-3172-5
10. DeBoer MD, Gurka MJ, Morrison JA, et al. Inter-relationships between the severity of metabolic syndrome, insulin and adiponectin and their relationship to future type 2 diabetes and cardiovascular disease. *Int J Obes*. 2016;40:1353-1359. doi:10.1038/ijo.2016.81
11. DeBoer MD, Gurka MJ, Woo JG, et al. Severity of the metabolic syndrome as a predictor of type 2 diabetes between childhood and adulthood: the Princeton Lipid Research Cohort Study. *Diabetologia*. 2015;58:2745-2752. doi:10.1007/s00125-015-3759-5
12. Jankowska A, Brzeziński M, Romanowicz-Sołtyszewska A, et al. Metabolic syndrome in obese children-clinical prevalence and risk factors. *Int J Environ Res Public Health*. 2021;18:1060. doi:10.3390/ijerph18031060
13. Fu L, Xie N, Qu F, et al. The association between polycystic ovary syndrome and metabolic syndrome in adolescents: a systematic review and meta-analysis. *Reprod Sci*. 2023;30:28-40. doi:10.1007/s43032-022-00864-8
14. Cheng L, Fu Q, Zhou L, et al. Dapagliflozin, metformin, monotherapy, or both in patients with metabolic syndrome. *Sci Rep*. 2021;11:24263. doi:10.1038/s41598-021-03773-z
15. Davies M, Pieber TR, Hartoft-Nielsen ML, et al. Effect of oral semaglutide compared with placebo and subcutaneous semaglutide on glycemic control in patients with type 2 diabetes: a randomized clinical trial. *JAMA*. 2017;318:1460-1470. doi:10.1001/jama.2017.14752
16. Hollander P, Gupta AK, Plodkowski R, et al. Effects of naltrexone sustained-release/bupropion sustained-release combination therapy on body weight and glycemic parameters in overweight and obese patients with type 2 diabetes. *Diabetes Care*. 2013;36:4022-4029. doi:10.2337/dc13-0234
17. Kim NH, Choi J, Kim YH, et al. Addition of fenofibrate to statins is associated with risk reduction of diabetic retinopathy progression in patients with type 2 diabetes and metabolic syndrome: a propensity-matched cohort study. *Diabetes Metab*. 2023;49:101428. doi:10.1016/j.diabet.2023.101428
18. Seki Y, Kasama K, Yokoyama R, et al. Bariatric surgery versus medical treatment in mildly obese patients with type 2 diabetes mellitus in Japan: propensity score-matched analysis on real-world data. *J Diabetes Invest*. 2022;13:74-84. doi:10.1111/jdi.13631
19. Rubino DM, Greenway FL, Khalid U, et al. Effect of weekly subcutaneous semaglutide vs daily liraglutide on body weight in adults with overweight or obesity without diabetes: the STEP 8 randomized clinical trial. *JAMA*. 2022;327:138-150. doi:10.1001/jama.2021.23619
20. Pi-Sunyer X, Astrup A, Fujioka K, et al. A randomized, controlled trial of 3.0 mg of Liraglutide in weight management. *NEJM*. 2015;373:11-22. doi:10.1056/NEJMoa1411892
21. Allison DB, Gadde KM, Garvey WT, et al. Controlled-release phentermine/topiramate in severely obese adults: a randomized controlled trial (EQUIP). *Obesity*. 2012;20:330-342. doi:10.1038/oby.2011.330

22. Rogers VW, Hart PH, Motyka E, et al. Impact of let's go! 5-2-1-0: a community-based, multisetting childhood obesity prevention program. *J Pediatr Psychol*. 2013;38:1010-1020. doi:10.1093/jpepsy/jst057
23. Marseglia A, Darin-Mattsson A, Skoog J, et al. Metabolic syndrome is associated with poor cognition: a population-based study of 70-year-old adults without dementia. *J Gerontol A Biol Sci Med Sci*. 2021;76:2275-2283. doi:10.1093/gerona/glab195
24. DeBoer MD, Filipp SL, Gurka MJ. Use of a metabolic syndrome severity Z score to track risk during treatment of prediabetes: an analysis of the Diabetes Prevention Program. *Diabetes Care*. 2018;41:2421-2430. doi:10.2337/dc18-1079
25. Carson V, Tremblay MS, Chaput JP, et al. Compositional analyses of the associations between sedentary time, different intensities of physical activity, and cardiometabolic biomarkers among children and youth from the United States. *PLoS ONE*. 2019;14:e0220009. doi:10.1371/journal.pone.0220009
26. Thabit H, Burns N, Shah S, et al. Prevalence and predictors of diabetes and cardiometabolic risk among construction workers in Ireland: the Construction Workers Health Trust screening study. *Diab Vasc Dis Res*. 2013;10:337-345. doi:10.1177/1479164113479808
27. Ma J, Yank V, Xiao L, et al. Translating the Diabetes Prevention Program lifestyle intervention for weight loss into primary care: a randomized trial. *JAMA Int Med*. 2013;173:113-121. doi:10.1001/2013.jamainternmed.987
28. Wadden TA, Volger S, Sarwer DB, et al. A two-year randomized trial of obesity treatment in primary care practice. *NEJM*. 2011;365:1969-1979. doi:10.1056/NEJMoa1109220
29. Luley C, Blaik A, Götz A, et al. Weight loss by telemonitoring of nutrition and physical activity in patients with metabolic syndrome for 1 year. *J Amer Coll Nutr*. 2014;33:363-374. doi:10.1080/07315724.2013.875437
30. Heiston EM, Eichner NZ, Gilbertson NM, et al. Exercise improves adiposopathy, insulin sensitivity and metabolic syndrome severity independent of intensity. *Exp Physiol*. 2020;105:632-640. doi:10.1113/EP088158
31. Peyer KL, Ellingson LD, Bus K, et al. Comparative effectiveness of guided weight loss and physical activity monitoring for weight loss and metabolic risks: a pilot study. *Prev Med Rep*. 2017;6:271-277. doi:10.1016/j.pmedr.2017.03.002
32. Mendoza-Núñez VM, Arista-Ugalde TL, Rosado-Pérez J, et al. Hypoglycemic and antioxidant effect of Tai chi exercise training in older adults with metabolic syndrome. *Clin Interv Aging*. 2018;13:523-531. doi:10.2147/CIA.S157584
33. Lau C, Yu R, Woo J. Effects of a 12-week hatha yoga intervention on metabolic risk and quality of life in Hong Kong Chinese adults with and without metabolic syndrome. *PLoS ONE*. 2015;10:e0130731. doi:10.1371/journal.pone.0130731
34. Grosso G, Stepaniak U, Micek A, et al. A Mediterranean-type diet is associated with better metabolic profile in urban Polish adults: results from the HAPIEE study. *Metabolism*. 2015;64:738-746. doi:10.1016/j.metabol.2015.02.007
35. Ren Z, Zhao A, Wang Y, et al. Association between dietary inflammatory index, C-reactive protein and metabolic syndrome: a cross-sectional study. *Nutrients*. 2018;10:831. doi:10.3390/nu10070831
36. Ghorabi S, Esteghamati A, Azam K, et al. Association between dietary inflammatory index and components of metabolic syndrome. *J Cardiovasc Thorac Res*. 2020;12:27-34. doi:10.34172/jcvtr.2020.05
37. Tørris C, Molin M, Småstuen MC. Lean fish consumption is associated with beneficial changes in the metabolic syndrome components: a 13-year follow-up study from the Norwegian Tromsø Study. *Nutrients*. 2017;9:247. doi:10.3390/nu9030247
38. Farhadnejad H, Parastouei K, Rostami H, et al. Dietary and lifestyle inflammatory scores are associated with increased risk of metabolic syndrome in Iranian adults. *Diabetol Metab Syndr*. 2021;13(1):30. doi:10.1186/s13098-021-00648-1
39. Bian S, Gao Y, Zhang M, et al. Dietary nutrient intake and metabolic syndrome risk in Chinese adults: a case-control study. *Nutr J*. 2013;12:106. doi:10.1186/1475-2891-12-106
40. van der Haar S, Hoevenaars FPM, van den Brink WJ, et al. Exploring the potential of personalized dietary advice for health improvement in motivated individuals with premetabolic syndrome: pretest-posttest study. *JMIR Form Res*. 2021;5:e25043. doi: 10.2196/25043
41. Mohammadpour S, Ghorbaninejad P, Janbozorgi N, et al. Associations between adherence to MIND diet and metabolic syndrome and general and abdominal obesity: a cross-sectional study. *Diabetol Metab Synd*. 2020;12:101. doi:10.1186/s13098-020-00611-6
42. Lin P, Chang CC, Yuan KC, et al. Red blood cell aggregation-associated dietary pattern predicts hyperlipidemia and metabolic syndrome. *Nutrients*. 2018;10:1127. doi:10.3390/nu10081127
43. Konieczna J, Fiol M, Colom A, et al. Does consumption of ultra-processed foods matter for liver health? Prospective analysis among older adults with metabolic syndrome. *Nutrients*. 2022;14:4142. doi:10.3390/nu14194142
44. Koochakpoor G, Daneshpour MS, Mirmiran P, et al. The effect of interaction between melanocortin-4 receptor polymorphism and dietary factors on the risk of metabolic syndrome. *Nutr Metab*. 2016;13:35. doi:10.1186/s12986-016-0092-z
45. Fan H, Wang Y, Ren Z, et al. Mediterranean diet lowers all-cause and cardiovascular mortality for patients with metabolic syndrome. *Diabetol Metab Syndr*. 2023;15:107. doi:10.1186/s13098-023-01052-7
46. LeBlanc EL, Patnode CD, Webber EM, et al. *Behavioral and Pharmacotherapy Weight Loss Interventions to Prevent Obesity-related Morbidity and Mortality in Adults: An Updated Systematic Review for the U.S. Preventive Services Task Force*. Agency for Healthcare Research and Quality (US); 2018. doi:10.1001/jama.2018.7777
47. Sandsdal RM, Juhl CR, Jensen SBK, et al. Combination of exercise and GLP-1 receptor agonist treatment reduces severity of metabolic syndrome, abdominal obesity, and inflammation: a randomized controlled trial. *Cardiovasc Diabetol*. 2023;22:41. doi:10.1186/s12933-023-01765-z.

48. Eisenberg D, Shikora SA, Aarts E, et al. 2022 American Society of Metabolic and Bariatric Surgery (ASMBS) and International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) indications for metabolic and bariatric surgery. *Obes Surg*. 2023;33:3-14. doi:10.1007/s11695-022-06332-1
49. Kahn R, Buse J, Ferrannini E, et al. The metabolic syndrome: time for a critical appraisal: joint statement from the American Diabetes Association and the European Association for the Study of Diabetes. *Diabetes Care*. 2005;28:2289-2304. doi:10.2337/diacare.28.9.2289
50. Lin JS, O'Connor EA, Evans CV, et al. Behavioral Counseling to Promote a Healthy Lifestyle for Cardiovascular Disease Prevention in Persons With Cardiovascular Risk Factors: An Updated Systematic Evidence Review for the U.S. Preventive Services Task Force. Agency for Healthcare Research and Quality (US); 2014.