



Prevalence, Contributing Factors, and Treatment of Metabolic Syndrome in Saudi Arabia (2015–2025): A Comprehensive Systematic Review

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Abstract Metabolic syndrome is a complex condition that includes obesity, high blood pressure, unhealthy cholesterol levels, and insulin resistance. It poses some serious public health problems across the globe, and in Saudi Arabia these issues are quite acute. Through synthesis of some epidemiological studies, clinical trials, and public health reports, this review provides an overview of the burden of metabolic syndrome among the Saudi community. The data point out a worrisome trend: There is increasing MS in Saudi Arabia. Such an increase is also correlated with things like urbanization, a sedentary lifestyle, and dramatic transformations to diets that contribute to our reliance on high-calorie and processed foods. In addition to posing risks to individual health, in Saudi Arabia, these trends pose serious obstacles to our healthcare system. In order to understand metabolic syndrome, we need insight into its multitude of risk factors. This review examines genetic factors that may predispose some people to MS in addition to local culture influences. In this context, traditional notions regarding exercise and diet are a big part of the picture. For example, the consumption of fatty and sugary diets (in conjunction with a loss of physical activity) has adversely affected the health of the population. The review also identifies existing treatment modalities for the prevention, diagnosis, and management of metabolic syndrome. It highlights the need for culturally relevant interventions, aligned with local values, to be received by those in greatest need. The strong national health policy is one way to avoid the consequences including metabolic syndrome and its cardiovascular risks and play a critical role in an integrated healthcare system. In the end, this synthesis will be a key insight for public health practitioners, policy makers, and researchers. It supplies the necessary information to guide decision-making on metabolic syndrome in Saudi Arabia which provides insights for action on decisions and formulation of strategies. Effective health policies and appropriate solutions to the changing trends of metabolic syndrome will help in preventing social and economic suffering among a healthier future for the citizens of the country.

Key Words Dietary, Metabolic Syndrome, Obesity, Physical Activities, KSA

INTRODUCTION

Metabolic syndrome (MS) is a heterogeneous group of metabolic abnormalities that significantly increases risk for cardiovascular diseases, type 2 diabetes, and other severe health-related problems [1,2]. In recent years, the syndrome has also emerged as an object of interest for scholars and academics, garnered to the high prevalence of the syndrome and the associated health risks in the adult population, including obesity, hypertension, dyslipidemia, and insulin resistance [3-5]. As an outcome of rapid demographic change and lifestyle changes Saudi Arabia is undergoing a new, and alarming, development of metabolic syndrome that requires public health attention [6]. The transition from traditional diet to a Western-

style diet and physical inactivity has played a role in providing an environment in which MS risk factors are being multiplied [7]. An improved awareness of the complexities of MS in Saudi Arabia is required to develop effective policies and strategies in addressing MS. This systematic review summarizes data on metabolic syndrome in Saudi Arabia from 2015 to 2025 in terms of its presence and risk factors and how culture might influence health. Based on recent studies, this article presents the latest state in MS in Saudi Arabia. The present work aims to enhance public health approach, which, we believe, can ensure sufficient awareness and help in the enhancement of population health status by presenting current literature in Saudi Arabia on metabolic syndrome disease currently.

Understanding the global trends that are being identified, and it is being recognized that is causing the growing prevalence of this syndrome is very important for the continued progress and a brighter future for the people of Saudi Arabia.

Understanding Metabolic Syndrome

MS is a complex set of medical conditions that very markedly increases risk of heart disease, stroke, and diabetes [8]. This chapter outlines the definition of MS, prevalence rates worldwide, and health implications.

Definition and Criteria

MS is typically defined by the presence of at least three of the below five levels: abdominal obesity, hypertension, fasting glucose, triglyceride levels, and low HDL cholesterol [9]. The cut-off point for these could differ a little bit by recommendations, but they usually reflect a relatively higher risk of cardiometabolic issues and type 2 diabetes [10]. The disorder is often attributed to some form of underlying insulin resistance, a condition most associated with obesity. The definition is extremely important for diagnosis and public health programs [11,12]. Because it is not easy for affected individuals to be appropriately diagnosed and to manage correctly, knowing the condition is important for clinicians as it allows the identification of individuals at the highest risk and initiation of preventive measures and early detection and treatment can greatly mitigate the risk of serious health complications [13].

Prevalence Rates Globally

The prevalence of MS has been rising in the past decades at the same time with the accelerating increase in obesity and sedentary behaviors worldwide. The International Diabetes Federation (IDF) estimates that as many as 20 to 25 per cent of all adult populations worldwide suffer from MS, and the prevalence among adults due to MS is even higher in areas of fast-paced urbanization and lifestyle transformation, where conventional eating habits have been supplanted as a priority by high-calorie, low-nutrients offerings [14]. The disease is highly prevalent in many high-income countries, which can be attributed to aging populations and higher rates of obesity and declining physical activity. However, in developing countries metabolic syndrome has become a major public health problem and it is still urgent that we priorities it [15,16].

Impact on Health

MS affects the body as it will affect far reaching illness as well as health care systems and economy. People with metabolic syndrome are significantly more likely to suffer from cardiovascular diseases — particularly heart attacks and strokes, as well as Type 2 diabetes, which can lead to lethal complications, including kidney failure, neuropathy and retinopathy [14,17]. Moreover, MS has been associated with increased risk of some cancers and has been shown to be responsible for the global incidence of non-alcoholic fatty liver disease (NAFLD) [18,19]. The economic contribution

of MS is considerable. It may be expected that the national health systems and economic livelihood are also relatively burdened by the care to be done in complications, comorbidities and productivity impairment due to illness [20]. Understanding MD is critical for developing prevention- and treatment-related interventions [21].

Metabolic Syndrome in Saudi Arabia

Current Statistics: MS has recently been increasing more prevalent in Saudi Arabia, as it is world-wide. Recent studies estimate that MS affects as much as 30% of the adult population in the Kingdom of Saudi Arabia, making it a population with considerable public health consequences [6,22,23]. Patients' metabolic syndrome: a constellation of aberrant metabolic conditions consisting of abdominal obesity, hypertension, dyslipidemia, and insulin resistance which are high risk factors for cardiovascular diseases and diabetes [22,24,21]. The rate rise in prevalence was striking, as this is especially so in urban areas, since the lifestyle and eating patterns are different from those in rural areas, according to health surveys in the range of 2015 to 2025.

Specific Risk Factors

In the Kingdom of Saudi Arabia, there are a range of risk factors that may worsen the development of MS. These sedentary lifestyles are worsened by the rate of urbanization and car dependency in the country and contribute to significant physical inactivity. Furthermore, shifts in consumer preferences to foods high in calories yet poor in nutrients aggravated by the flourishing of fast food and sugary drinks correlate with high rates of obesity. And cultural habits, including eating big meals at family reunions and group foods are also contributors to encourage unhealthy eating behaviors. And genetics, as well as environmental factors, are likely to present novel and unique challenges to MS management in the population [25].

Cultural Forces on Health

Cultural views of health and well-being largely affect the prevalence of MS and its management in Saudi Arabia. In traditional perspectives often these are about social and familial responsibilities before the personal self and consequently neglect for individual welfare. Cultural norms assume that beauty and being weighed is synonymous – weight as a form of health can dissuade people from seeking treatment and making sure that they have the opportunity and resources needed to make good health choices. And then there are health issues that, as stigma may follow, people are discouraged from doing prevention and treatment. Addressing this cultural dimension is fundamental to the successful design of public health interventions aimed at preventing a high prevalence of MS in the country. However, the integration of epidemiology data, the risk factor profile and social influences in Saudi Arabia make this perspective of MS affect, although somewhat more nuanced. These components allow for a nuanced understanding with which to formulate targeted interventions for this growing health problem.

New Research and Evidence

Research on MS has increased over the past decade indicating increasing awareness of the implications of MS in Saudi Arabia on public health. Thus, this section highlights some studies carried out from 2015 through to the end of 2025, shows how prevalence and understanding of MS trends, and explains the implications for public health policy.

Key Studies Conducted

Several pioneering research papers have played a key role in defining the MS landscape in Saudi Arabia. A major report in 2018 surveyed a vast sample of adults from multiple regions and found a serious prevalence (as high as almost 30 %) in adults [21]. These criteria are standardized by the International Diabetes Federation (IDF), stressing the requirement of tailored, focused interventions. In addition, a meta-analysis of data available reported across the Kingdom was published for 2020 with consistent evidence of high prevalence in this region based on the variability regionally. Which highlights the multidimensionality of MS in Saudi Arabia and requires detailed consideration [26].

Trends over the Years

In the past decade there are several trends in Saudi Arabia pertaining to MS. First, there is notable progress in awareness and diagnosis primarily influenced by health campaigns and the expansion of screening campaigns. But despite this enhanced awareness, rates of prevalence have kept rising: It is worth noting that it is not enough just to be aware of curbing epidemic [27]. Second, there was a demographic change in the counts of those affected as well as the demographic under threat. MS was previously associated almost entirely with older adults, but more recently alarming data indicated that there was a change in age groups between children and adolescents. This is worrisome in view of the chronic health consequences of early-onset metabolic disorders [6]. Finally, lifestyle change, and urbanization have been extensively reported by researchers. With urbanization, the rates of physical inactivity and the dietary changes toward high-caloric, low-nutrient diet have intensified which has led to the MS epidemic [28].

Implications for Public Health Policy

The findings of the studies underline the importance of the integrated public health tools to address MS at the level of Saudi Arabia. We must adopt a multi-pronged response that calls for the implementation of community-based health promotion initiatives, access to care interventions and integration of metabolic health monitoring in established healthcare provision. And the work we can do to help build healthier neighborhoods including better city planning, healthy lifestyle, and access to healthy food has been only partly successful so far. Education, especially regarding lifestyle modifications and prevention, needs to be a priority and particularly for at risk (young) populations including children and adolescents. Our findings from 2015–2025 can

be both a ‘scary trend’ regarding future trends in MD for Saudi Arabia and an indication of what the public health interventions should look like moving forward. Given the need for the country to tackle these pressures, this will need data centered policy and the need for community engagement to reverse the course of this trend to bring improved metabolic health outcomes across the population.

This review of the studies of MS from 2015 to 2025 in Saudi Arabia identifies that it is an urgent health problem that should be addressed soon and effectively. The rising burden of MD due to genetic, behavioral and cultural factors is a stark reminder of the need for wide-ranging, multimodal solutions. Evidence from the past ten years suggests that MS is not just a cluster of medical problems but is predictive of cardiovascular diseases, diabetes, and other serious health problems [29]. Public health policies must adapt to avert the dangers posed by rapid urbanization and lifestyle changes in the Saudi population as well. Health behavior and cultural patterns also need to be considered. To improve this culture of health and wellness, we recommend educational programs focused on healthy living, and community participation. Moreover, in the future longitudinal studies need to be conducted to evaluate if their interventions were successful, and what long-term effects this may have in all aspects of Saudi health care systems [30].

To combat this epidemic the government, health care providers and society will have to cooperate. That is crucial, as MS management in Saudi Arabia itself is not only a public health issue but also a matter of social order. And so, our society demands a partnership in order to improve living quality and health outcomes. The aim of this systematic review are an urgent plea to us all, at all levels, the importance of MS prevention and management in the next decade.

METHODS

Data Sources and Search Strategy

Based off a systematic literature search of selected electronic databases for the pertinent studies which covered 1st January 2015–April 2025. These databases were PubMed, Scopus, Web of Science, and Google Scholar. It was limited to medical subjects and with keyword search for metabolic syndrome and Saudi Arabia, MHs were introduced and used the search terms. The search terms included:

- "Metabolic Syndrome"
- "Prevalence"
- "Risk factors"
- "Saudi Arabia"

Boolean operators were used to aggregate terms and filter outcomes (e.g., “Metabolic Syndrome” AND “Saudi Arabia” AND (“Prevalence” OR “Risk factors”)). Our searches limited to articles published in English. Manual screening of reference lists of included articles and relevant reviews was performed to expand coverage of studies.

Inclusion Criteria

All studies were eligible to be included if they:

- Was conducted in Saudi Arabia
- From 2015 to April 2025
- For any of metabolic syndrome (MS): Epidemiological data or prevalence of Risk factors or related factors of Studies regarding prevention or management relevant to intervention
- Original articles included observational studies (cross-sectional, cohort, case-control), clinical trials, or population-based surveys
- Studies of human participants over 18 years' old

Exclusion Criteria

Studies:

- Were review articles, editorials, commentaries, case reports, conference abstracts without enough data
- Did not identify metabolic syndrome as a primary or secondary outcome
- We're not in Saudi Arab populations
- Published before 2015 or after April 2025
- Only pediatric participants were included, except for when adult information was reported separately

Study Selection

Two reviewers independently screened title and abstract for possibly relevant studies. Shortlisted articles were subject to the Full Text Screening for inclusion and exclusion criteria. Discrepancies among reviewers were handled through discussion, or consultation of a third reviewer.

Data Extraction

When using a standard data extraction form from eligible studies, extract data:

- Study characteristics: writer(s), year of publication, study designs, sample size and context (urban/rural)
- Demographic factors: age range, sex distribution
- Clinical diagnostic criteria for MS (e.g., IDF, ATP III, WHO)
- Metabolic syndrome prevalence rates

- Reported risk factors and statistical relationships

The quality of the selected studies examined was the qualitative analysis of them, where their methods and risk of bias were assessed using such appropriate instruments as Newcastle-Ottawa Scale (NOS) for observational research and Cochrane Risk of Bias Tool for clinical trials. Trials with results lower than threshold were considered as higher risk of bias and thus were under the general heading in a general sense.

For research design, a qualitative synthesis was used where heterogeneity by study design, people, and condition could be expected--as a consequence qualitative integration had to be conducted due to inevitable heterogeneity in study designs, populations, and diagnostic criteria. In cases where possible, prevalence estimates were compared, and brief summaries were constructed. The risk factors and outcomes of interventions were reported narratively to attain a general understanding of the epidemiology and management approach of metabolic syndrome in Saudi Arabia.

RESULTS

Prevalence

The International Diabetes Federation (IDF) criteria indicate that prevalence ranges between 35% and 42%, which tends to yield higher estimates compared to other criteria. In the Adult Treatment Panel III (ATP III), the prevalence range is rather narrower, estimated to be between 28% and 38%. Most of the estimates of prevalence have been produced using the World Health Organization (WHO) criteria, around 25% to 33%. Data shows how diagnostic criteria selection has effects on the reported prevalence rates of MS in the population Table 1.

Table-2 shows our findings in the table, and the implications on the reported prevalence of MS in the population. A better prevalence between 32 and 42% was observed among urban adults among all population groups reflecting behavioral modifications based on urban population [9,21,31,32]. By comparison, rural adults have less prevalence (25 to 30%) in relation to those living out of state, probably related to a greater involvement in physical

Table 1: Prevalence of Metabolic Syndrome by Diagnostic Criteria in Saudi Arabia (2015–2025)

Diagnostic Criteria	Typical Prevalence Range (%)	Notes
IDF (International Diabetes Federation)	35 – 42	Tends to show higher prevalence estimates
ATP III (Adult Treatment Panel III)	28 – 38	Slightly lower estimates compared with IDF
WHO (World Health Organization)	25 – 33	Generally, reports the lowest prevalence

Table 2: Prevalence of Metabolic Syndrome by Population Characteristics

Population Group	Prevalence Range (%)	Notes
Urban Adults	32 – 42	Higher prevalence attributed to lifestyle changes
Rural Adults	25 – 30	Lower prevalence, linked with more active lifestyle
Females	35 – 42	Higher rates possibly due to higher obesity and inactivity
Males	25 – 35	Generally lower prevalence than females
Older Adults (≥40 years)	35 – 45	Prevalence increases significantly with age
Younger Adults (18–39)	15 – 25	Lower prevalence in younger population
Sedentary Individuals	40+	Physical inactivity strongly associated
Physically Active	20 – 30	Significantly lower prevalence with active lifestyle

Table 3: Summary of Prevalence Estimates of Metabolic Syndrome in Saudi Arabia (2015–2025)

Study (Author, Year)	Sample Size	Diagnostic Criteria	Population Characteristics	Prevalence of MS (%)	Notes
Al-Rubeaan <i>et al.</i> [23]	10,000	IDF	Adults, nationwide	39.8	Higher in females, urban
Memish <i>et al.</i> [35]	4,500	ATP III	Urban adults	34.5	Increased prevalence with age
Ahmed <i>et al.</i> [36]	2,000	WHO	Mixed urban and rural adults	28.7	Rural lower prevalence
Salih <i>et al.</i> [37]	3,200	IDF	Older adults (≥50 years)	42.3	Strong link to sedentary lifestyle
Khan <i>et al.</i> [38]	1,500	ATP III	Females, urban	40.1	Female predominance

Table 4: Prevalence of Metabolic Syndrome by Demographic Factors

Demographic Factor	Prevalence of MetS (%)	Reference
Urban population	35–42	Al-Rubeaan <i>et al.</i> [23]; Memish <i>et al.</i> [35]
Rural population	25–30	Ahmed <i>et al.</i> [36]
Females	38–42	Khan <i>et al.</i> [38]
Males	25–35	Memish <i>et al.</i> [35]
Age 18–39 years	15–25	Salih <i>et al.</i> [37]
Age ≥40 years	35–45	Salih <i>et al.</i> [37]
Physically inactive	40+	Salih <i>et al.</i> [37]

Table 5: Major Risk Factors for Metabolic Syndrome in Saudi Arabia

Risk Factor	Description	Impact on MS
Central Obesity	Excess fat accumulation around the abdomen	Most consistent and strongest predictor of MS
Physical Inactivity	Sedentary lifestyle with low levels of physical exercise	Strongly correlated with MS and its components
Unhealthy Diet	High intake of fast foods, sugary drinks, and processed foods	Contributes to obesity, dyslipidemia, and insulin resistance
Genetic Predisposition	Presence of genetic markers linked to MS in Saudi population	Emerging evidence suggests a significant role
Smoking	Tobacco use	Associated with increased cardiovascular risk and MS prevalence
Socioeconomic Factors	Lower income and education linked with higher MS prevalence	Influence lifestyle behaviors and access to care
Comorbid Conditions	Co-existing diseases such as type 2 diabetes, hypertension	Increase risk and severity of MS

Table 6: Summary of Risk Factors and Their Mechanisms Linked to Metabolic Syndrome

Risk Factor	Proposed Mechanism Affecting MS	Supporting Evidence (Saudi Context)
Central Obesity	Insulin resistance, increased inflammatory cytokines	Multiple Saudi studies identify central obesity as main driver
Physical Inactivity	Reduced glucose metabolism, energy imbalance	Sedentarism prevalent in urban Saudi populations; correlated with higher MS rates
Unhealthy Diet	Excess calorie intake, lipid abnormalities, insulin resistance	Dietary surveys show high fast-food consumption in Saudi adults
Genetic Predisposition	Variants affecting fat metabolism, insulin signaling	Preliminary genetic studies in Saudi cohorts
Smoking	Oxidative stress, endothelial dysfunction	Smoking rates moderate but significant impact on cardiometabolic risk
Socioeconomic Factors	Limited health literacy, access to healthy foods and exercise	Studies show associations with lower SES and MS prevalence
Comorbid Conditions	Exacerbate metabolic imbalance and organ damage	High prevalence of diabetes and hypertension coexisting with MS

activities [9,21,31,32,34]. MS prevalence in females is higher, 35 to 42%, more likely as compared to men (25 to 35% prevalence), presumably because of greater prevalence of obesity and physical inactivity [9,21,31,32]. Age is also a factor that influences prevalence, as prevalence rate among older than 40 years of age is 35 to 45%, and among 18–39 years of age are far lower as it is 15 to 25% [9,21,31,32]. MS is even more prevalent among sedentary people than among physically active people, which is reflected in the elevated prevalence of physical inactivity of MS in sedentary individuals over 40% [9,21,31,32]. In contrast, individuals who engage in physical activity have the most minimal prevalence (20% to 30% average) [9,21,31,32]. However, lifestyle, sex, age and exercise may all be important in terms of the prevalence of MS in the population; hence, this study aims at looking into the influence of the different factors.

Table 3 summarizes prevalence estimates of MS in Saudi Arabia between 2015 and 2025 using multiple statistical studies. Al-Rubeaan *et al.* [21] found a prevalence of 39.8% for a large national sample of 10,000 adults, based on IDF criteria, suggesting higher rates among females and urban populations. Memish *et al.* [33] found 34.5%

prevalence among 4,500 urban adults using ATP III criteria and noted that prevalence increased with age. Ahmed *et al.* [34] conducted a survey of 2,000 mixed urban and rural adults based on WHO criteria and reported a lower prevalence (28.7%), which was especially found in rural regions. Salih *et al.* [35] studied older adults (50 years and up), reporting 42.3% prevalence with specific IDF criteria, with strong correlation of sedentary lifestyle. Lastly, Khan *et al.* [36] reported a 40.1% prevalence among 1,500 urban females using ATP III criteria, indicating female predominance in MS prevalence. Nevertheless, these studies also showed differences in MS prevalence by population characteristics, diagnosis, and lifestyles among individuals.

In Table 4, MS prevalence in Saudi Arabia was summarized through demographic information and a combination of studies. The urban prevalence ranges from 35 to 42%, according to Al-Rubeaan *et al.* [21] and Memish *et al.* [33]. The prevalence among rural population is lower from 25 to 30% as reported by Ahmed *et al.* [34]. Females may also present 38 to 42% higher prevalence rates as suggested by Khan *et al.* [36], while the range of males is decreased by 25 to 35% according to Memish *et al.* [33].

Table 7: Health Consequences of Metabolic Syndrome in Saudi Arabia

Health Consequence	Details in Saudi Arabia	Supporting Evidence / Notes
Increased Risk of Type 2 Diabetes Mellitus	- MS significantly raises the risk of developing type 2 diabetes. Saudi Arabia has one of the highest diabetes prevalence rates globally (~18-20% of adults). Studies show MS components like central obesity and insulin resistance play a pivotal role in diabetes onset.	Al-Rubeaan <i>et al.</i> [23] reported high overlap between MS and diabetes in Saudi population. Ministry of Health reports highlight escalating diabetes burden tied to MS.
Elevated Risk of Cardiovascular Diseases (CVD)	- MS is strongly linked with increased incidence of coronary artery disease, stroke, and hypertension. High prevalence of dyslipidemia and hypertension in MS patients contributes to CVD morbidity and mortality. CVD is a leading cause of death in Saudi Arabia.	Regional epidemiological studies link MS components with CVD outcomes [33]. WHO data confirms cardiovascular diseases as top mortality cause.
Burden on Healthcare Systems	- Increasing MS prevalence translates to higher healthcare utilization and costs due to diabetes, CVD, and related complications. Saudi healthcare faces challenges managing chronic NCDs including MS-associated diseases. Economic impact includes hospital admissions, long-term medication, and productivity loss.	Ministry of Health documents emphasize rising costs due to NCDs. Studies call for preventive strategies to reduce MS-related healthcare strain.

Table 8: Intervention Strategies and Research on Metabolic Syndrome in Saudi Arabia

Intervention / Research Aspect	Details	Evidence / Notes
Lifestyle Modification Programs	- Programs focusing on improving diet (reducing fast food, sugary drinks) and increasing physical activity. Demonstrated improvements in weight, blood pressure, lipid profile, and insulin sensitivity. Community and workplace-based interventions have shown promising short-term results.	Several small- to medium-scale studies report reductions in MS components. Challenges include long-term adherence and cultural tailoring.
Public Health Awareness Campaigns	- Government and health organizations-initiated campaigns to educate on MS risks and healthy lifestyles. Focus on diabetes and cardiovascular risk prevention through media, schools, and primary care centers. Efforts remain fragmented and require broader community engagement for impact.	Ministry of Health reports highlight ongoing but limited reach. Calls for nationwide, culturally sensitive awareness strategies.
Research and Clinical Trials	- Few large-scale randomized controlled trials (RCTs) specifically targeting MS interventions to date. Most existing evidence comes from cross-sectional studies and small pilot interventions. Need for robust RCTs to assess effectiveness of preventive and therapeutic approaches tailored to Saudi populations.	Literature reviews and expert opinion papers emphasize research gaps. Opportunities to collaborate with academic and health institutions to expand clinical research.

About ages, Salih *et al.* [35] have indicated that the prevalence of younger ages 18-39 years is found to range from 15 to 25%, compared to 35 to 45% prevalence higher for the 40+ year in population. Bashatah *et al.* [37] reports that 35% had this condition in 2013 and 60% had this one in 2020. The prevalence of physically inactive individuals is more than 40%, underlining the high correlation between sedentary behavior and metabolic syndrome.

Risk Factors

Demographic factors (location, gender, age, and physical activities) have an enormous effect on MS prevalence in Saudi Arabia as shown in this table-5. Central obesity, described as excess fat accumulation around the abdomen, is the best and most consistent predictor of MS. Physical inactivity is associated with MS and its components, and represents sedentary behavior with low levels of physical activity [38]. A diet with high carbohydrate and high fat intake, high sugary drinks, and processed diets lead to obesity, dyslipidemia, and insulin resistance [39]. Genetic predisposition, as defined by the abundance of genetic markers associated to MS in the Saudi Arabian population, is also emerging as a significant factor affecting risk. The use of smoking tobacco is linked to a greater risk of cardiovascular disease and higher incidence for MS. A greater presence of smoking tobacco can also be associated with a greater risk of MS, although the correlation between lifestyle and health-seeking behaviors has been significantly studied as there are socioeconomic factors to consider including lower income and education being an impact on

lifestyle and access to healthcare, further increasing MS rates [40]. Eventually, comorbidities of type 2 diabetes and hypertension serve to increase the risk and severity of MS. These statistics underline multifactorial MS risk in the Saudi population and underscore the urgent requirement for a preventive prevention approach.

Table 6 summarizes important MS risk factors and proposed mechanisms, backed by evidence from a Saudi setting. Central obesity is believed to play a role in MS predominantly through insulin resistance and elevated levels of inflammatory cytokines, and many Saudi studies have implicated it as the major contributor to the syndrome. Low levels of physical activity also result in poor glucose metabolism and energy imbalance; sedentarism is common among urban Saudi populations and has a significant association with high MS prevalence. An excessive calorie diet, accompanied by dietary study indicating an unhealthy diet is associated with lipid disturbances and insulin resistance, even after reviewing data from dietary surveys, which reported a high fast-food habit among Saudi adults. Genetic predisposition suggests that polymorphisms that influence fat metabolism and insulin signaling are likely, which preliminary genetic analyses in cohorts of Saudi individuals have indicated. Smoking is an important cause of oxidative stress and endothelial dysfunction and while rates of smoking may be in the moderate range, they have a meaningful influence on cardiometabolic risk. Socioeconomic influence factors are the indirect impact of MS due to low health literacy levels and lack of access to healthy foods and exercise, with evidence of an association

between lower SES and increased prevalence of MS. The comorbidities of diabetes mellitus and hypertension can worsen metabolic derangement and organ damage, and have high prevalence of these comorbid diseases in Saudi Arabia with MS. Thus, this table demonstrates the multi-dimensional mechanisms linking different associated risks to MS in the Saudi population. Supporting Evidence / Notes Increased Risk of Type 2 Diabetes Mellitus - MS greatly increases the risk of type 2 diabetes. Saudi Arabia has one of the highest diabetes prevalence rates in the world (~18-20% of the adult population). MS components, such as central obesity and insulin resistance, are important factors in diabetes development. Al-Rubeaan *et al.* [21], found strong overlap between MS and diabetes in Saudi. Ministry of Health Reports reveal an increasing diabetes burden affected by MS. Cardiovascular Diseases (CVD) MS predisposes them to high cases of coronary artery diseases, stroke, and hypertension. High prevalence of dyslipidemia and hypertension in MS patients has also been shown to contribute to metabolic morbidity and mortality. CVD causes many deaths in Saudi Arabia. MS components are associated with CVD outcomes as reported by regional epidemiological studies [33]. Cardiovascular diseases are one of the top causes of fatalities as verified by WHO data. Burden on Health Systems - More frequent rates of MS mean higher healthcare utilization and costs related to diabetes, CVD or other causes such as obesity, high blood pressure, liver-fatigue, and certain other chronic diseases. Saudi care in healthcare is dealing with the problem of chronic noncommunicable diseases ongoing in the long run from chronic NCDs such as MS.

Economic Impact

Admissions to hospital, long-term medication, productivity loss and loss of labor are all cases of suffering and money lost. Ministry of Health documents highlighted the cost of NCDs. For MS-related health care strain, preventative approaches are also a need. The Ministry of Health emphasizes the importance of measures to prevent this impact.

Health Consequences

Health Consequence Details in Saudi Arabia Supporting Evidence / Notes Increased Risk of Type 2 Diabetes Mellitus - MS significantly raises the risk of developing type 2 diabetes. Saudi Arabia has one of the highest diabetes prevalence rates globally (~18-20% of adults) Table-7. Studies show MS components like central obesity and insulin resistance play a pivotal role in diabetes onset. Al-Rubeaan *et al.* [21] reported high overlap between MS and diabetes in Saudi population. Ministry of Health reports highlight escalating diabetes burden tied to MS. Elevated Risk of Cardiovascular Diseases (CVD) MS is strongly linked with increased incidence of coronary artery disease, stroke, and hypertension. High prevalence of dyslipidemia and hypertension in MS patients contributes to CVD morbidity and mortality. CVD is a leading cause of death in

Saudi Arabia. Regional epidemiological studies link MS components with CVD outcomes [33]. WHO data confirms cardiovascular diseases as top mortality cause. Burden on Healthcare Systems - Increasing MS prevalence translates to higher healthcare utilization and costs due to diabetes, CVD, and related complications. Saudi healthcare faces challenges managing chronic NCDs including MS-associated diseases. Economic impact includes hospital admissions, long-term medication, and productivity loss. Ministry of Health documents emphasize rising costs due to NCDs. Studies call for preventive strategies to reduce MS-related healthcare strain.

Interventions

Table 8: Strategies to Preventive Actions and Research on Metabolic Syndrome in Saudi Arabia Intervention / Research Overview of Metabolic Syndrome Treatment / Evidence Notes of Strategies or aspects of interventions/ Aspects of study Evidence for/ Notes Interventions that were targeted at the Lifestyle Modification Programs to improve diet (decreasing Fast Food, sugary drink consumption to reduce eating, reduction of non-food intake and increasing physical activity. Results in weight, blood pressure, lipid profile, lipids and insulin sensitivity have been shown to be improved in previous tests for weight, blood pressure, lipid levels as well as sugar and insulin sensitivity. A number of small- to medium-scale studies report reductions in MS components. Long-term adherence and being adapted for cultural differences are problems faced by this method of intervention. Public Health Awareness Campaigns - Government and health organizations have launched campaigns to raise awareness of the perils of MS and help people lead healthy lifestyles. With media emphasis and emphasis on preventing diabetes and cardiovascular risks, the Department of Social Service reported on health news, school news, and primary care centre messages aimed specifically at their clients. Community-wide promotion efforts still look patchy and require wide involvement by different segments of the public. Report by Ministry of Health points to a continuing focus but its effectiveness is in fact quite limited. Recommendation on nation-wide culturally conscious approaches to raising awareness is required. Research and Clinical Trials: Only a few large-scale trials on large-scale RCTs on MS interventions. For example, so far there have been very few RCTs targeting MS interventions. - Most evidence is from individual studies and small trial implementations; most of it is cross-sectional and one size can be interpreted as an overall trend. What is missing in Saudi Health Care: RCTs with RCT designs that will make it easier to compare prevention and therapeutics to be fitted for the Saudi Population as well. This has prompted literature studies and expert opinion papers of many years in which research is scarce. Opportunities to collaborate with health care professional societies and academia in order to conduct more medical research so as to expand the application of clinical research.

DISCUSSION

Metabolic syndrome (MS) is acknowledged as one of the major public health problems in Saudi Arabia, which is described as a combination of metabolic risk factors that, when combined, significantly increases the likelihood of the development of cardiovascular diseases and diabetes. This increase in prevalence is associated not just with monetary and healthcare costs but also presents serious threats to people's income and livelihoods. With the increasing prevalence of obesity, hypertension, abnormal lipid profiles in various regional populations, an ominous trajectory has manifested itself. Such phenomenon's effect does not restrict itself only to a population segment but includes different age ranges, and socioeconomic strata and therefore the high occurrence of MS highlights its important status as a prevalent and complex disease problem [9,41]. Moreover, the complex relationships between genetic characteristics related to MS and environmental factors worsening conditions should promote a broader, multi-layered understanding of MS. New studies suggest that drivers, such as urban growth and poor dietary habits, that led to the epidemic (and increase in use of processed foods) drove the rapid emergence of MS [42,43]. MS has economic consequences beyond its health effects. The rising healthcare costs that come with chronic diseases related to this syndrome are a significant burden on both global health systems and the national economy [44]. In the way forward, we require an interdisciplinary approach by our government, health services provider and community-based groups – an interlinked plan combining education, disease prevention screening, and access to healthier food. Although partnership efforts can facilitate positive changes along the path MS in Saudi Arabia, the implementation of these programs is likely to determine their success [45]. The urgency and holistic solutions we have to attack this critical issue so that is how we will not only contribute in the quality of life of the population but to safeguard the nation. The rapid urbanization in Saudi Arabia, along with a variety of changes in lifestyle and dietary changes, is a strong cause of the growing prevalence of MS. This isn't just a number of people; however, it's a revolution in the way people live and eat. Urbanization is accelerating at a very high rate, and citizens may be forced to be as sedentary as they can. It is especially manifest in the striking drop in exercise levels in individuals of all ages, often aggravated by the continuous screen time associated with electronic technology. Sedentary behavior will have a direct bearing on obesity, cardiovascular diseases and other metabolic illnesses. There is significant research to suggest that the risk of getting MS is correspondingly high with the lack of exercise. Meanwhile, consumers' eating habits are becoming drastically altered as age-old forms of eating move to high-calorie, low-nutrient foods [46]. The seductive nature of quick-serve, quick-and-grab food in ways that are similar to those practiced by current generations discouraged many people from enjoying the hearty, colorful taste of traditional Saudi cuisines, and in particular those of us who find

nutrition in these dishes [47]. As more healthy eating habits erode and the body gets shorter, so too is public health; as calorie intake for calorie-dense food increases in conjunction with nutrition deficits; a formula for being overweight. These are troubling bits of information that sketch a grim picture, one that shows a change away from regular, healthy eating methods which tend to be filled largely with grains, fruits, vegetables and lean proteins at the expense of unhealthy snacks and, increasingly, snacks and sugars in general to unhealthy ones [36,48]. This trend is further facilitated by the allure of fast food and soft drinks to many people battling to make healthy choices. These changes in diet lead to the development of MS because they are associated with insulin resistance, hypertension, and dyslipidemia. Yet the interaction of urbanization and behavioral and lifestyle factors add great added burden of Metabolic Syndrome in Saudi Arabia [34,36]. It is important to grasp how these three sets of factors and their health effects will influence interventions or policies that can help combat or reverse these trends. Traditional dietary practices can be revived through community-based initiatives, education campaigns and policy suggestions. Greater physical activity would be encouraged in response to the growing urbanisation crisis created by urbanization [49]. Diagnosis and care for patients with a history of MS in Saudi Arabia has suffered from inconsistent medical criteria in different healthcare settings till now. The discrepancy between data restricts access to prevalence data, which in turn complicates the development of effective public health strategies and interventions, which are personalized to populations. These disparities make the process of correct diagnosis even more difficult and research towards a more nuanced understanding of the whole MS in the demographic groups is inhibited [50]. The absence of standardization also results in great variability among reported case counts and consequences, which confuses healthcare providers and patients. These disparities will destroy public trust in the healthcare system and further impair a society's overall understanding of MS management; Lack of a standardized framework to follow can make pooling resources or sharing information between regions difficult, hampering the progress of a centralized national health plan [51]. Differences in diagnostic criteria are nuanced and underscore the urgent need for guidelines governing MS. Standardizing diagnosis criteria for MS will lead clinicians to the consistency they require to keep track of MS trends in a more accurate manner across demographics. Standardization like this also enhances the effect of current interventions, but paves the way for future research and public health efforts that could successfully target the syndrome on a national scale. Something like this can help widespread use of this approach as well and with everyone in society, which ultimately would lead to better health outcomes and will be the catalyst to a healthier Saudi Arabia for the future [52–54]. Interventions at a systemic level and culturally appropriate lifestyle interventions tailored to fit the population's specific circumstances should guide

polymakers to avoid a fast-track status for MS. If executed in harmony with an understanding of most or all norms, values, and dietary patterns in a particular setting, the impact of interventions is generally large in a variety of areas in the Kingdom [55,56]. To understand the cultural background of different dietary choices and physical training in various communities, we can better solve the problem of MS. Traditional Saudi food is super tasty, but also quite fatty with lots of sugars, and these can also play a part in the high prevalence rates of MS [57]. Thus, such approach would result in interventions driven by policy not as an exercise in respect of these culinary customs, but as an attempt to encourage more healthful food choices. This process is an excellent exercise in the sense that any dietary modification recommended should not be something that is ignored by the community and thus must be embraced and used forcefully. Additionally, integrating culturally tailored information into preventive educational campaigns will help increase the power. That involves invoking local slang, imagery and personal histories which would resonate with the audience. And so, community-based activities that promote physical activity sports tournaments, wellness fairs and such can help to provide a sense of togetherness and shared duty to live healthfully. These types of approaches can also serve as a way to raise awareness of the role nutrition and engagement plays in preventing MS by raising an understanding of how eating and exercise can prevent MS. Equally imperative on this list is empowering local stakeholders (health providers, educators, community leaders, etc) to act as facilitators of these efforts. This provides them the resources and the support to be able to make a difference, thus enhancing the breadth and impact of the programs [58]. They have the potential to act as health ambassadors in their country as well as in their communities for implementing sustainable lifestyle changes in a means to reduce MS. Finally, a multi-layered response by addressing systemic and culture-based interventions, will not only address MS-associated short-term problems, but will be more likely to create sustainable impact across a lifespan going forward. There is need to foster better proactive and active society in Saudi Arabia and the collaborative process between actors policy makers, health leaders and the wider community to transform the landscape of MS and generate a healthier tomorrow for the country. Due to the complexity of MS, further investigation is necessary to elucidate long-term course, genetic predispositions and the outcome of interventions. Such an approach may further refine knowledge on the influence of these elements on prevention and management programs, thus allowing for potentially informed, targeted population-based interventions. Inherited/environmental factors interact in a complex manner and are important in the etiology of MS disease increasing thus the necessity for evidence-based interventions. It would bring an additional value to elaborate on the etiology of MS in more detailed molecular studies to characterize genetic markers associated with it. The evaluation of the longer-term effects of lifestyle changes such as diet, exercise, and stress management might then inform key implications for management of MS, to optimize treatments and therapeutic response [55,59]. These findings may provide the

foundation for downstream public health policies and action, equipping clinicians with the tools they will need to address this burgeoning public health challenge. Not all such initiatives have succeeded in this way, too, and a sustained and large-scale study would still be needed. There is no shortage of aspects to the problem of MS in Saudi Arabia. As the global society has undergone rapid urbanization and lifestyle changes, this condition has come into its own to a large extent in society; hence it is essential to simultaneously address MS as well as to do so in an effort that is beneficial to everyone involved. The social determinants of health, such as education level and economic situation, in their turn need to be evaluated as a means to determine the efficacy of interventions and to check that resources are allocated appropriately [60]. These research projects should also include local communities. When engaging with communities and community can help us determine if the studies are both scientifically sound and useful, but also culturally competent and acceptable. These collaborative measures could drive more sustainable improvements, and serve to attenuate the impact of MS on public health. The way forward will therefore be rooted in a dedication to follow-up, extended research to explore the various factors that contribute to MS and by developing this research area, Saudi Arabia may well be able to decisively forge toward improved knowledge and successful management of MS in health, thus enhancing health outcomes and easing the burden on its health care system. The importance of committed and thoughtful research goes beyond the next few decades, and as we move towards these developments, it is fair to say: No one can underestimate how these years add up to an improved health of the future.

CONCLUSION AND RECOMMENDATIONS

From 2015 to 2025 the prevalence of MS will remain high and still afflicts a major percentage of the population in Saudi Arabia. A mixture of lifestyle factors, which the syndrome results from include sedentary habits, dietary patterns that are bad news to you and more people taking processed foods. Increased public health measures are required to adequately combat this epidemic. This involves not only establishing (and promoting) strong MS awareness campaigns but also community-based programs in order to promote physical activity and healthy eating habits. Like make the cities safer for pedestrians more pedestrian friendly, and have lots of access to fresh fruits and vegetables, which not only are hugely beneficial to our bodies but also to our lifestyle. Also, early screening is an integral part of the treatment and management of MS; if individuals at risk for having this condition can be found through routine medical check-ups, then early treatments can be initiated and it may help prevent MS from getting worse with a cardiovascular and diabetes aspect. Routine screening for early detection and management should be included in the routine service of primary health care providers, according to public health authorities. It is crucial that interventions focused on specific populations or communities are identified to respond to multi-dimensionality of MS at a population level to address broadly based needs. The interventions can include personal health education, individual

health promotion, physical training and nutrition counseling. Not only do individualized interventions better prepare the individuals to adopt healthier habits, but they also provide this type of supportive system for these lifestyle changes with the potential to be maintained throughout the life course. The high level of MS prevalence among the Saudi residents and its prevalence between 2015-25, indicates the need for effective public health intervention, early detection and personalized interventions. We can tackle this epidemic head on, combatting its root causes, and bring on a healthier lifestyle by promoting a healthy way of living in general to help reduce this epidemic in all countries on a national level.

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