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REVIEW ARTICLE

Cardiovascular Disease in Saudi Arabia: Facts and the Way Forward

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Abstract

Cardiovascular diseases (CVDs) remain a major health concern globally. While some risk factors for CVDs are non-modifiable, other determinants like obesity, hypertension, type-2 diabetes and dyslipidemia can be mitigated by a wide plethora of measures to control CVD morbidity and mortality. Those determinants have been on the rise in Saudi Arabia, exacerbated by sedentary lifestyle. The Saudi Vision 2030 aims to reduce CVD clinical and economic burden and to scale up vitality and longevity; in a new era of comprehensive healthcare. From a health economics standpoint, CVDs entail a burden on healthcare systems directly through expenditure and indirectly through years living with the disease, low productivity, premature morbidity and mortality. This manuscript reviews current CV health and unmet needs in Saudi Arabia, discusses G20 countries' initiatives on primary prevention: public health measures, awareness programs; and proposes national registries and digital solutions to facilitate population-specific research, improve CV surveillance and alleviate CVD burden in Saudi Arabia.

Keywords: Cardiovascular disease, Cardiovascular risk factors, Prevention, Saudi Arabia, Saudi Vision 2030

1. Introduction

In the last two decades, life expectancy in Saudi Arabia has increased from 69.08 years in 1990 to 75.13 years in 2019, as reported by The World Bank [1]. However, with the aging population comes the challenges of dealing with chronic illnesses such as diabetes, cancer and cardiovascular diseases (CVDs) [2,3]. According to the World Health Organization (WHO), the definition of CVDs includes coronary heart disease, cerebrovascular disease, peripheral arterial disease, congenital heart disease, deep vein thrombosis and pulmonary embolism [4].

Aside from the rise of CVDs in the aging population, it is also alarmingly spreading in the younger generation. In the United States of America, a study showed how unhealthy body weights among youth resulted in significantly increased CVD healthcare expenditure [5]. Cumulative healthcare expenditures (including CVDs-related costs) increase steadily with obesity, with an average of 8.6% increase in overweight, 18.8% in obese and 76% in morbidly obese people [5]. These findings suggest that the lifetime risk for CVD increases in people who are overweight or obese in their youth. However, little efforts have been made into strategies to reduce CV risks at a younger age [6,7]. There has been an interest lately in studying the widespread of non-communicable diseases, of which CVDs, in the younger generation and the multiple challenges a society is faced with to overcome them [8]. In addition to poor quality of life, earlier onset of CVDs

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is alarming in many ways: (1) the younger population constitutes the workforce; (2) chronic diseases, such as CVDs, have been associated with early retirement; and (3) long-term healthcare costs. Moreover, another factor that contributes to the rise of CVDs is urbanization, which has been strongly paired with increased smoking, unhealthy diet, sedentary lifestyle and obesity [9,10].

The aim of this current work is to compare the burden of CVDs in Saudi Arabia to that of other developed countries and focus on the CV risk factors and some proposed solutions. This will direct the focus afterwards in proposing a strategic direction to mitigate CV risks and alleviate the CVD burden, in terms of policies and practical measures, complying with the 2030 healthcare and economic vision for Saudi Arabia. The healthcare sector transformation program is set to prioritize public health and disease prevention, in addition to improving access to healthcare services through optimal coverage, comprehensive and equitable geographical distribution, as well as improving the quality of healthcare delivery and enhancing e-health services [11].

2. The economic impact of CVDs globally and in Saudi Arabia

Worldwide, developed countries are struggling with CVDs economic burden and government-based reimbursement schemes for in-patient and out-patient medical care [10]. Despite some success in addressing CVDs globally, CVDs remain the leading cause of death in several developed countries [12–15]. In France, over $23 billion (14% of total health insurance reimbursements) were directed towards CVDs and related chronic treatment, which is close to 0.9% of 2020 gross domestic product (GDP) [16]. In China, 2016 data suggests CVD health expenditure of around $14 billion, which was around 0.1% of 2016 GDP [17]. In the United States, over $400 billion, which is around 2% of GDP, were spent on CVD expenditure in 2018, including direct healthcare costs and productivity loss [18]. In Australia, $3.7 billion (11% of healthcare expenditure) was dedicated to cover inpatient care for CVDs in 2012–2013, which is around 0.2% of 2013 GDP [19]. In Russia, CVD burden costs the economy over $30 billion in 2009, equivalent to 2.8% of the GDP [20]. The economic burden of CVDs in Turkey was estimated to be $10.2 billion in 2016, making up 1.2% of 2016 GDP [21]. These figures reflect the economic burden of CVDs globally and the lack of a current perfect model to deal with CVDs.

List of abbreviations

CAD	Coronary artery disease
COVID-19	Corona Virus Disease 2019 caused by SARS-CoV-2
CV	Cardiovascular
CVD	Cardiovascular Disease
GDP	Gross Domestic Product
MOH	Ministry of Health
NCDR	National Cardiovascular Data Registry
RIKS-HIA	Register of Information and Knowledge about Swedish Heart Intensive Care Admissions
UK	United Kingdom
WHO	World Health Organization

In Saudi Arabia, health care burden collectively consumes over 8% (approximately $56 billion) of the government's total budget [22]. The economic burden of CVD in Saudi Arabia was estimated to be $3.5 billion ($1.9 billion in direct healthcare costs and $1.6 billion in indirect costs from loss of productivity) in 2016. It is estimated that this number will triple to $9.8 billion in 2035 [23,24]. The need to promote healthful practices to limit the spread of vascular diseases, including CVDs, has been long identified. However, individual scattered efforts to control this epidemic did not meet the expectation and so far yielded rather modest outcomes [2,25]. Therefore government-backed strategies to improve healthcare in general and CVD prevention in particular are needed [26].

Interventions should aim first at a primary prevention level focused on mitigating CV risk factors and preventing CVD onset, as well as secondary prevention level focused on diagnosing CVDs early on, through timely and comprehensive screening, to prevent complications.

Primary prevention is a cost-effective measure, whereby investing effort and resources into eliminating CV risk factors yields high returns. Screening and early diagnosis of CVDs should enforce strict management of modifiable risk factors (i.e. hyperlipidemia, smoking and diabetes mellitus) and therefore stabilizing the conditions and prevent disease complications and its economic and social consequences.

3. CVD landscape in Saudi Arabia

3.1. Prevalence of CVD in Saudi Arabia

In 2016, there were 201,300 Saudi nationals living with CVD, including 149,600 adults with ischemic heart disease and 51,700 with cerebrovascular disease. It is estimated that CVD accounts for over 45% of all deaths [23,27]. In 2005, the prevalence of

coronary artery disease (CAD) in Saudi Arabia was estimated to be 5.5% [27–29]. The current prevalence of CVD in Saudi Arabia is expected to be significantly higher, given the rise of CVD risk factors in the country (obesity, diabetes mellitus, dyslipidemia, hypertension and others) [30]. Additionally, the 2012 extrapolated prevalence of heart failure in Saudi Arabia was estimated at around 1.2% (for a total population of around 29 million) and a 2013 study showed that 20% of patients admitted for acute coronary syndrome suffered from heart failure [31–33]. The disability burden of CVD in Saudi in 2017 was 10,921 years per 100,000 individuals of healthy life lost to disability (YDL) [34].

3.2. Determinants of CVDs in Saudi Arabia

Lately, Saudi Arabia's lifestyle has become permissive to the onset of non-communicable diseases of the developed world. Despite socioeconomic disparities within Saudi Arabia, newer generations have generally adopted a sedentary lifestyle [35,36]. This is likely multifactorial, due to the weather environment limiting outdoor activities and walking or biking to work, along with the influence of globalization ranging from social media and video-games use to cosmopolitan fat- and sugar-rich diet. The increasingly sedentary lifestyle of Saudis negatively impacted their well-being. In particular, rates of hypertension and hyperlipidemia almost doubled since the start of the new millennium [2].

The Global Obesity Observatory showed an increase in the prevalence of obesity from 26.4% amongst men and 44% amongst women in the year 2000, to 31.5% amongst men and 50.4% amongst women in the year 2005. Although obesity rates were lower in 2019 with 19.2% amongst men and 21.4% amongst women, the rates of overweight are strikingly high, comprising 38.2% amongst the sampled population and making more than half of the population either obese or overweight [37]. A more recent 2020 nationwide cross-sectional survey, reported obesity prevalence in Saudi Arabia at 24.7%, with consistently higher rates of several obesity-associated morbidities [38]. As reported in a systematic review in 2016, Saudi women in particular are more susceptible to CVDs due partly to the low level of physical activity ranging between 53% and 98% that likely led to higher prevalence of CVD risks: hypertension (22%), diabetes (ranging between 10% and 28%), overweight (27%) and obesity (40%) [39]. The higher rates of obesity amongst women was also further underscored by the above-mentioned reports from the Global Obesity Observatory [37]. Regardless of trends, overweight and obesity are highly prevalent in Saudi Arabia, and they are mostly attributed to sedentary lifestyle and unhealthy diet [40,41]. The prevalence of tobacco use went from 12.2% in 2013 to 21.4% in 2018 and 20% in 2019 [42–45]. In addition, globalization, urbanization, the rise of an aging population, as well as socioeconomic changes and stress, can all contribute to the rise of CVDs [4]. Data collected between April 2019 and February 2021 on the government's e-service portal (ABSHER) were analyzed for prevalence of major chronic disease risk factors. Fig. 1 reports data on the prevalence of the major CV risk enhancers in Saudi Arabia, according to a 2017 study and to data extracted from the ABSHER platform in 2021 [30,46]. Discrepancies might be due to changes occurring between 2017 and 2020, the much larger sample of the 2020 and potential under-estimations due to the nature of self-reported data [47].

3.3. Addressing the modifiable risk factors

Lifestyle modifications, which include healthy diets, regular exercise and avoiding smoking remain an essential part of healthy living. Weight control and weight loss can be achieved through two main domains: the promotion of physical activity, and adopting healthy diet habits.

Several lifestyle and diet habits interventions have been studied previously. A trial carried out in a primary healthcare center in Northern Sweden included 151 subjects at risk for CVDs, randomized them to intervention and control arms. The intervention consisted of exercise (supervised endurance and circuit training in groups three times a week for three months) and diet (five group sessions of diet counselling with a dietitian). One year later, waist circumference (-1.9 cm, $P < 0.001$), waist-to-hip ratio (-0.01, $P < 0.01$) and diastolic blood pressure (-2.3 mmHg, $P < 0.05$) have all significantly decreased [48]. Another study evaluated the efficacy of lifestyle intervention (counselling on smoking, exercise, nutrition, and stress) on CV risk mitigation in middle-aged people by randomizing them to either counseling intervention group or standard of care group. Compared to the control (standard of care) arm, the intervention group had significantly lower total cholesterol levels (-0.41 mmol/L, $P < 0.05$) and lower systolic blood pressure (-7.49 mmHg, $P < 0.05$). In the secondary prevention group, no major outcome changes were recorded, highlighting the effectiveness of primary prevention in mitigating CV risk [49]. Healthy behavior and CV risks were described in women with at least one CV risk factor, subjected either to lifestyle intervention or to standard of care

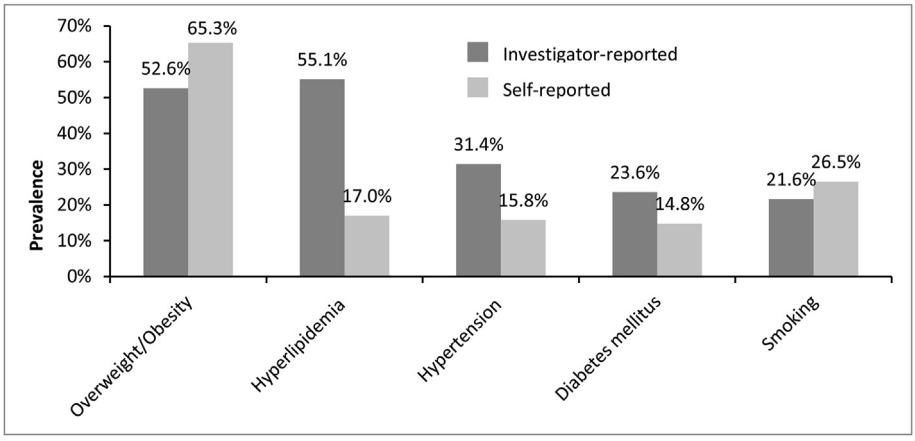

Fig. 1. ***Prevalence of CV risk enhancers in Saudi Arabia.*** *Investigator-reported data was collected in 2017 in primary care facilities. Around 50% of subjects had more than 3 CV risk factors. Self-reported data were extracted from the ABSHER platform in 2021, according to self-administered questionnaires completed by 713,094 participants. Despite the very large sample from the ABSHER platform, figures might be underestimated due to the nature of self-reported data.*

(control). A significantly higher proportion of women improved their eating habits in the intervention group (58.4%) compared to the standard of care (control) (33.1%) as well as physical activity improvement (57.3% versus 42.3%, respectively, $P < 0.001$). Blood pressure significantly decreased by 9.1% from baseline in the intervention group (systolic −5.9 mmHg and diastolic −3.8 mmHg, $P < 0.05$), HDL-cholesterol went up by 2.6 mg/dl ($P < 0.05$), along with an improvement in other CV risk factors, contributing to an overall decrease in the 10-year CV risk by 0.9% ($P < 0.05$) [50]. Studies carried out in the last decade have shown that LDL-cholesterol targets are only achieved in around 30% of patients [51]. A large proportion of patients with dyslipidemia are left unidentified and untreated in Saudi Arabia; underscoring gaps in screening, treatment and compliance with international guidelines [51]. In 2022, the World Heart Federation reiterated the importance of lipid management for the success of CV risk management, requiring diverse approaches from access to screening and lipid-lowering medications (statins and combinations as needed), to risk stratification, health literacy and health policy changes [52]. In 2022, the Saudi Guidelines for Dyslipidemia Management were published, aiming to provide a comprehensive framework for controlling dyslipidemia in the country and its cardiovascular consequences [53].

The JuvenTUM project in Germany assessed the outcomes of a physical education program on school children and found that health-related lessons at school and an increased in physical activity resulted in decreased waist circumference by 1.7 cm ($P < 0.001$), more pronounced among children with obesity (−3.2 cm, $P < 0.001$) [54]. In Tunisia, a school-based program to promote healthy lifestyles included educational sessions on tobacco use, physical activity and healthy nutrition. Students were evaluated before and after the intervention. Knowledge, behaviors, and intentions in the intervention group improved. In terms of smoking, at baseline, 11.5% of students knew that smoking causes CVDs *versus* 46.3% after the intervention, $P < 0.001$; and while only 49.1% of students were aware of the lung cancer risk, the proportion increased to 84.9% after the intervention ($P < 0.001$). The intention to exercise increased from 87.1% of students to 96.2%, $P < 0.001$; and twice as many students started exercising at least 6 days a week ($P < 0.001$) [55]. In addition, food manufacturers have been motivated by clear nutrition labels to reformulate healthier products; with sodium reduction ranking first, followed by increased dietary fibers, and reduced saturated fatty acids and sugar content [56]. A projection study reported that between 2018 and 2037, the mandatory added sugar label on food packaging would prevent 354,400 cases of CVDs and a total of $31 billion in net healthcare costs [57].

Based on the encouraging outcomes of programs and policies to promote healthful lifestyles, nationwide strategies to promote healthy nutrition are highly recommended [58]. Table 1 summarizes some of the main Saudi initiatives aimed at reducing CV modifiable risk factors. It is evident that Saudi Arabia has abundant strategies and policies to promote heart-healthy lifestyles, but are yet to be widely adopted and enforced [59].

3.4. Mitigating the non-modifiable risk factors

While some CVD risk factors are inevitable, their consequences on health might be mitigated. Older age is associated with increased CV risks, but

Table 1. Saudi initiatives to reduce modifiable CV risk factors.

Initiative	Purpose	Reference
Saudi Guideline for Tobacco	To improve smoking cessation services, in light of global evidence on the harms of smoking on individuals and communities.	[60]
Obesity Control & Prevention Strategy 2030	To monitor and control obesity and promote healthy lifestyle and prevention strategies.	[61]
RASHAKA Program	To promote a healthy lifestyle by improving dietary behaviors, increasing physical activity, and awareness of obesity risks.	[62]
Saudi Hypertension Guideline	Updated guidelines on hypertension management, designed for general practice.	[63]
KSA National Strategy for Diet and Physical Activity	To direct developmental efforts towards limiting diseases related to unhealthy diet and low physical activity, engaging different stakeholders in health, and raising public awareness on the impacts of diet and physical activity on health.	[64]
City humanization and walkability	Revamp streets and roads to make them pedestrian-friendly and promote healthier lifestyle.	[65,66]

increasing exercise and reducing calorie-intake as people grow older can help increase muscle mass and prevent obesity, diabetes and hyperlipidemia; thus promoting vitality and longevity [67–69]. Recent studies suggest that 2.5–5 h of physical exercise per week will provide cardioprotective benefits [70].

Familial hyperlipidemia has been well studied in a recent study carried out in 5 Arabian Gulf countries including Saudi Arabia. This study reported a threefold higher prevalence of familial hyperlipidemia in the Gulf region when compared to western societies [71]. Although the genetic driving factor of familial hyperlipidemia might be a non-modifiable risk factor at this point, early screening can turn this risk factor into a modifiable one with strict control of risk factors [72,73] The same applies to premature early coronary artery disease and sudden cardiac death, where early screening can identify those who are at risk and prompt timely and aggressive management of their risk factors as per guidelines to prevent complications and death [52]. This will require a multidisciplinary approach including geneticists, endocrinologists, and adult and pediatric cardiologists. The Saudi government looks at CVD as a public health priority. Therefore, in 2022 the government allocated a one-time payment of $3000 per patient over five years for screening tests, healthcare costs and lipid-lowering therapies; with the aim to reduce CVD mortality and morbidity. It is estimated to screen most of the Saudi population for CV risk factors within a five-year timeframe [73]. The 2022 report on CVD recommends the development of a national CVD risk screening program, mostly at the primary care level, with multiple access points in Saudi Arabia communities [73]. Additionally, Saudi population have shown an overall acceptance of genetic testing; which could help identify individuals (and families) with treatable or manageable genetic profile predisposing them to CVD, among other conditions [74]. This will create opportunities for government-run and sponsored efforts to perform genetic testing on cases with premature cardiac arrest and cardiomyopathy; as well as creating a cardiogenomics database for family mapping, research purposes and future therapeutic potentials.

4. Curbing CVDs in Saudi Arabia: where do we stand?

4.1. Pillars of healthcare systems

In Saudi Arabia, healthcare and therapeutic management are largely provided to the population by the government for free, whether at primary, secondary or tertiary levels (Fig. 2) [26,75]. Reforms in the primary healthcare system have been started to ensure that primary healthcare centers throughout Saudi Arabia's 13 regional health directorates have the capacity to oversee other healthcare centers and to serve as the gateway to other medical services [76–78]. Secondary healthcare level includes the general hospitals and the tertiary level comprises of further specialized hospitals. Decentralization of healthcare services has boosted this sector. In addition, a fourth level of care is sometimes defined as the medical cities (referral hospitals) that provide specialized diagnostic and therapeutic services, in addition to research and teaching activities [75]. Access to specialized healthcare services in Saudi Arabia is not entirely limited to in-person physical care. A recently launched initiative in 2018, the "Seha" virtual hospital at the Ministry of Health (MOH) headquarters, has a central cardiac imaging and CV information center where cardiac data are reviewed and complex cases are discussed with periphery centers through a National Virtual Heart committee. The Seha virtual hospital improved access to healthcare services, patients' satisfaction along with productivity and efficiency [79].

A 2021 study compared the US and Saudi healthcare systems with a focus on the WHO 6 building

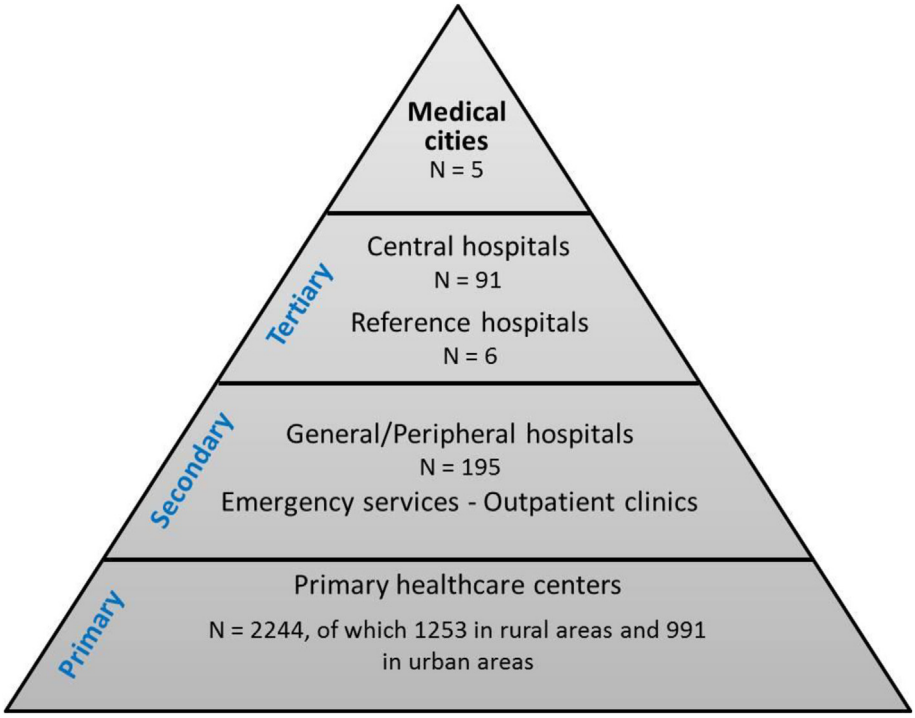

Fig. 2. ***Healthcare hierarchy in Saudi Arabia.*** *There are a total of 2244 primary care centers in charge of basic curative, preventive and health promotive services. Patients requiring more advanced medical care are referred to one of the 292 MOH hospitals (secondary and tertiary level). The fourth level includes medical cities that only receive a very selected population of patients referred from tertiary care centers or from outside the referral system [75,76].*

blocks, which include: service delivery, health workforce, health information system, access to medicines and technologies, health system financing, and leadership/governance [80]. These blocks are the healthcare transformation objectives of Saudi Vision 2030, starting with improved access to healthcare services, improved quality and efficiency of healthcare, reduced waiting times, and upscaling of disease prevention activities [11]. The study showed that although the healthcare budget is almost double in the US (18% GDP) compared to Saudi Arabia (9.2% GDP), some health outcomes are similar; such as infant mortality. The life expectancy in Saudi Arabia increased by 30 years from 1960 to 2019 to reach 74.9 years, while in the US, life expectancy increased by 10 years from 69.8 to 78.5 years [80].

4.2. Assets and gaps

4.2.1. Cardiology clinics

According to the Health Statistical Year Book's Chapter 2 on health resources, there are 26 specialized diabetes and endocrinology centers, 600 smoking cessation centers and 24 cardiology centers and departments affiliated with MOH throughout Saudi Arabia [22]. The distribution of healthcare facilities throughout the country along with the equity and access to healthcare services are key strategic points in the governments' 2030 vision [11]. Although there might be limitations to the access of healthcare in some geographical locations, poorly controlled diabetes, hypertension, dyslipidemia and other CV risk factors could be attributed to other factors, such as patients' compliance. This factor can be addressed by raising awareness at the level of primary care offices and national-level campaigns and ensuring the best quality of care is implemented and regulated [81].

4.2.2. Differences in CV risks in urban and rural Saudi Arabia

A recent study highlighted a health gap between urban and rural communities in Saudi Arabia, reporting significantly higher rates of diabetes, obesity, hypertension, and stress among people living in urban areas [26]. Furthermore, rural communities had lower rates of stress and unhealthy diet habits. While urban lifestyle is thought to be associated with greater CV risk factors, one explanation to these findings is the "urbanization of rural life", relying more on machine-operated tools for agriculture and less on physically demanding work [26]. This study also highlighted the gender and age-based differences, with higher rates of obesity (BMI

>35 kg/m^2), stress and lack of education among women as well as higher rates of unhealthy diet habits among the youth [26].

4.2.3. Shortcomings of the Saudi health information system

In 2010, the lack of a national health information system (HIS) was underscored. Between 2011 and 2019 39% of governmental hospitals had implemented HIS while only 29% of primary care centers had HIS [80,82]. As a matter of fact, inadequate coordination has been reported among medical care levels; 30% of Saudi patients with hypertension did not have diagnosis records in 2010 based on a providers' survey [83,84]. The fragmented healthcare system and the challenges in coordination between referral and referring centers, coupled with the shortage of primary care physicians, resulted in compromised quality of care with repeated testing and little emphasis on prevention [75]. These system gaps have prompted the Saudi government to launch a series of initiatives and programs to promote the local healthcare system [75,85]. A systematic integration of a HIS across the country's healthcare facilities will improve treatment coordination, minimize operational expenses, improve patient outcome and satisfaction, allow for nationwide research initiatives; for CV health promotion and overall scaling up of healthcare services.

There also should be an enhanced focus on CV prevention, which starts at the primary care centers. Primary healthcare centers governed by the MOH have expanded recently in Saudi Arabia [82]. Since they are at the frontline in the efforts towards reducing CVD burden, primary care physicians (PCPs) should be offered high-quality evidence-based practice training and continuous medical education to raise awareness about the latest recommendations and guidelines [86]. The quality of care should also be enforced by the MOH to make sure the CV risk factors are well-managed.

4.2.4. Manpower shortage

Although in some hospitals the advanced medical diagnostic and therapeutic modalities have been available, the issues with resources allocation and the shortage of qualified medical personnel have made their use limited. This highlights the need to assess the shortage nationally and focus on addressing the educational needs within the country and focused abroad scholarship programs in deficient areas to invest in the local manpower. All the deficient degrees (i.e. nurse practitioners) should have a formal classification under the Saudi Commission for Health Specialties (SCFHS) to facilitate their transition to work after their training. In 2021, Saudi Arabia had a population of 34, 110, 821 [87]. Per 10,000 population, the country had 29.2 physicians (total of 99,617 physicians), 57.7 nurses (total of 196,795 nurses), 9.0 pharmacists (total of 30,840 pharmacists), and 22.6 hospital beds (total of 77,090 beds) [87]. In the United States per 10,000 population in 2021, there were 32.2 physicians, 154.5 nurses and there was a shortage of at least another 33 nurses per 10,000 populations in 2022 [88,89]. In China per 10,000 population in 2021, there were 29.7 physicians and 35.5 nurses [90,91]. In Qatar in 2020, there were 77.3 physicians and 27.4 nurses per 10,000 population [92]. Importantly, in 2017, Saudi Arabia ranked 4th (after Kuwait, Qatar, and Libya) and in 2018 it ranked 5th (after Qatar, Kuwait, Libya and the United Arab Emirates) in terms of density of physicians and nurses in the region [93]. Although Saudi Arabia has comparable and sometimes better healthcare provider rates compared to other countries, the need for more physicians, nurses and nurse practitioners is still evident [94,95].

4.2.5. Limited access to fitness centers

The expansion of the gym industry in Saudi Arabia reflects the greater awareness among the community on the benefits of exercise; although unhealthy diet habits and obesity rates are still on the rise [96]. The number of men's fitness centers in Saudi Arabia has increased from 485,000 in 2012 to 890,000 in 2017. While women-only fitness centers have become more available and popular since they were licensed in 2017. Earlier data suggest over 90% of Saudi women report being physically inactive, partly due to the absence of adapted facilities in their neighborhood [97]. According to a nationwide survey, membership fees to fitness clubs in Saudi Arabia range between $240 and $1000 per month, and reports indicate that 40% of Saudi women are reluctant to join a fitness center due to costs [97]. Organized fitness centers are located in major cities such as: Riyadh, Jeddah, Dammam, Al-Khobar, Makkah and Medina; while other cities have limited fitness centers. The promotion of physical activity in Saudi Arabia warrants health promotion initiatives by all concerned stakeholders, to lessen the discrepancy in physical activity between genders and provide widely accessible and affordable community fitness centers [98,99].

4.3. Awareness and behavioral change

While the healthcare system is being revamped and the focus now is on promoting better sustainable and accessible care, as well as better workforce, the Saudi population needs to be educated on the

importance of seeking medical care in a timely manner. Population education can be achieved through mass media (television, social media platforms, etc.) and through targeted patient education at medical centers, schools and focused communities.

In particular, people at high risk of CVD or with established CVD must be encouraged to seek medical care, starting at the primary care level. Communities should trust their primary care physicians and should be made aware of the efficiency of *primary prevention* of CVDs and early diagnosis of CVDs, to ensure timely management takes place. In the absence of local guidelines for CVD prevention, internationally recognized guidelines could guide medical practice in the prevention of CVDs [100].

Furthermore, tools for *behavioral changes* should be widely provided to promote healthy lifestyle given the rise of obesity. A recent systematic review showed that behavioral counselling on diet and physical activity measures have been shown to modestly reduce BP over a period of 6–18 months. However, counselling effects are more pronounced when it comes to lowering LDL level, reducing it by a mean of 2.2 mg/dl [101]. The effects of social media and advertisements have been another challenge in promoting unhealthy diet. The MOH can use the same platforms on social media to reach out to the public to promote counseling behaviors. The strikingly high rates of overweight and obesity among the Saudi population, has also led to a marked increase in the rate of bariatric surgery [102]. The MOH should ensure that insurance companies cover the management of obesity, including behavioral counseling.

4.4. Leveraging CV healthcare

A multidisciplinary approach can be implemented in primary care clinics throughout the Saudi Arabian territories. Primary healthcare clinics could be expanded to include a CVD prevention program; and step up CV health prevention across all Saudi Arabia provinces. The government has indeed recognized the need for healthcare restructuring and the importance of leveraging care in primary care centers, which are at the forefront of prevention and timely diagnosis of CV risk factors [26]. These prevention programs can be implemented virtually, for selected follow-up appointments. This could help solve the issue of understaffed medical facilities that hinder PCPs from fulfilling their role in CV prevention [103].

4.5. Stakeholders in CV health

The goal of containing CV risk factors and promoting healthful practices requires a collaboration of governmental institutions, municipalities, schools and colleges, food manufactures and restaurants, as well as the community and individuals. The MOH operates over half of medical facilities across the country, and other governmental hospitals directed by the Ministry of Defense, the Ministry of National Guard, the Ministry of Interior, and King Faisal Specialist hospitals. These governmental institutions could liaise with other organizations such as sports medicine association, sports for all federation, Saudi Heart Association, Saudi Society of Endocrinology and Metabolism, Saudi Society for Food and Nutrition and others to design and implement programs to combat sedentary lifestyle and promote CV health [98]. The Saudi Health Council has streamlined a seamless connection between different healthcare providers to ensure that quality, ease of access as well as prevention and early detection metrics are met. The promotion of physical activity will have a greater impact on society when joint efforts are made amongst the previously mentioned ministries [98]. Awareness must be spread at every level and policies must be set out to govern practices, promote use of resources and enforce quality measures. In 2017, at a roundtable in Riyadh, the Saudi Heart Association, together with the World Heart Federation and the Saudi Health Council, laid down roadblocks to improve CVD management at the patient, clinician and healthcare system levels in light of the 2017 cholesterol roadmap. The panel will convene again to reflect on main barriers to optimal CVD prevention and management and offer solutions to the Saudi Health Council [52].

5. National registries and health initiatives

5.1. An overview of databases and programs in G20 countries

There are many international registries that have positively affected the field of cardiovascular care. This section is designed to highlight the ones that made a huge impact internationally.

The ***National Cardiovascular Data Registry*** (NCDR®) in the USA has been established by the American College of Cardiology. Data collected from different hospitals are submitted through a certified vendor (on a quarterly basis), a clinical specialist with experience in data abstraction, or through a web-based data collection tool. Hospital registries include the following: Chest Pain - MI Registry™, AFib Ablation Registry™, CathPCI Registry®, EP Device Implant Registry™, IMPACT Registry®, LAAO Registry™, PVI Registry™, and the STS/ACC TVT Registry™. Outpatient registries

include data from electronic health records, transmitted through the PINNACLE registry® or the Diabetes Collaborative Registry®. More information can be accessed on the following link: https://cvquality.acc.org/NCDR-Home/registries.

In France, there are three major clinical cardiology registries: Common diseases, Intervention and Rare Diseases registries; operating through the *EURObservational Registry Program*. There are also two prevention registries (EuroAspire IV and EuroAspire V). Data are collected and entered into the registry by physicians, using an online electronic case report form.

In Sweden, the *SWEDEHEART* online cardiac registry covers all hospitals in Sweden and collects data on long-term follow-up. This continuous registry combined all four pre-existing registries, spanning heart surgery, percutaneous coronary intervention and coronary angiography, and secondary prevention; in addition to the Register of Information and Knowledge about Swedish Heart Intensive Care Admissions (*RIKS-HIA registry*), *SCAAR*, *SEPHIA* and others that can be accessed on the following link: https://www.ucr.uu.se/swedeheart/index.php?option=com_content&view=article&id=220&Itemid=538. Currently, data are manually entered into the registry by physicians, but plans for the automated extraction of data from electronic health records are underway. A recent study analyzed the effectiveness of statins in preventing major CV events after coronary artery bypass grafting, in patients entered into the SWEDEHEART registry and other nationwide databases. The large sample size (>35,000) increases the precision and the reliability of study results. Statins were found to decrease the incidence of CV events by 44%, all-cause death by 47%, CV death by 46%, myocardial infarction by 39%, and stroke by 34%; re-emphasizing the role of statins in secondary prevention of CVDs in patients who have undergone revascularization [104]. Another important finding from the SWEDEHEART cohort is the higher risk of recurrent CV events after myocardial infarction among patients with family history of early-onset CVDs; which means that higher-risk patients would be more closely monitored to prevent recurrent events [104]. This highlights the importance of large-scale national registries to see the impact of therapy on CVDs.

In Italy, the National Prevention Plan focuses on disease prevention; involving not only the health system, but also other stakeholders [105]. The *CUORE project*, developed by the Italian Ministry of Health and coordinated by the National Institute of Health, gives general practitioners a platform to enter data and estimate risk scores for their patients. A recommended plan is then drafted for patients in terms of lifestyle modifications. The data is also collected for epidemiological research and to provide trends for individual patients. A 10-year CV risk assessment from CUORE data showed that 31% of the 140,000-strong sample had at least two risk assessments, of which 11% shifted to lower risk categories after a year with 0.6 mmHg drop in systolic blood pressure, a 0.5 mmHg drop in diastolic blood pressure, and 4.1 mg/dl drop in total cholesterol and a 3% reduction in the number of smokers [106]. In addition, they provide dedicated training sessions to primary care practitioners on CV risk identification and prevention. They have implemented some successful initiatives; such as the *initiative to reduce salt* in manufactured foods along with smoking ban that has been extended to electronic cigarettes. The Italian undertakings to curb CVDs have proven to be partially effective [107,108]. The age-adjusted mortality rate of CVD per 100,000 people fell from 267.1 in 1980 to 141.3 in 2000 among adult men and from 161.3 in 1980 to 78.8 in 2000 among adult women; and 55% of the decrease was attributed to CV risk factor mitigation [107]. In 2015, while smoking and hypertension rates had decreased in Italy, dyslipidemia and obesity rates have increased; highlighting the importance of addressing all CV risk factors. Therefore, their CVD burden remain prevalent and require continuous risk mitigation efforts [108].

Examples of other initiatives globally include those implemented in Japan, Germany, United Kingdom (UK) and Sweden.

Japan has always had one of the world's lowest rates of CVDS despite the unfavorable lifestyle changes to their community [109,110]. Moreover, despite reports of increased levels of LDL-cholesterol, body mass index and diabetes rates, age-adjusted death rates from heart disease in Japan declined by 61% between 1980 and 2012. This is partially due to an 8.4 mmHg decrease in systolic blood pressure (associated with a 24.4% lower death rate), a decrease smoking prevalence (believed to have contributed to 11.1% of death rate fall) and an increased physical activity (explaining 7.5% of all delayed or prevented deaths) [111]. Importantly, a study reported that reduction in CV mortality in Japan is due to simultaneous improvements of risk factors, resulting in a cumulative risk reduction; enhanced by better pharmacological care [111]. A comprehensive management chart for CVDs has been proposed to evaluate the status of patients being treated for CV risk factors [109]. Commendably, Japan has issued a law (the 2018 *Stroke and*

Cardiovascular Disease Control Act) to reinforce countermeasures implemented in Japan against CVDs such as community health activities, public education, and treatment guidelines.

A study in Germany, 25 years ago, determined the effectiveness of community intervention programs in reducing CV risks, highlighting the benefits of primary prevention [112]. A Policy and Practice paper by the Federal Ministry of Health in Germany reflects on the country's actions to prevent chronic diseases [113]. Some of the initiatives launched are mentioned below. *The Preventive Health Care Act* was made into law in 2015 with the focus to prevent non-communicable diseases (such as CVDs) from manifesting themselves through rigorous prevention measures. The *National Action Plan IN FORM* is a national initiative to promote healthy diets and physical activity and has been successful in achieving health behavior changes among German communities. An *Alliance for Health Literacy* was established in Germany in 2017 to promote health literacy and it involves healthcare providers, policymakers, health insurance funds and patient representatives. Private organizations also played a role in creating programs to promote CV health. A German health insurer initiated '*KardioPro*', a program to promote primary, secondary and guideline-directed prevention of CVDs. This program proved to be effective with a 23.5% reduction in the composite all-cause mortality, acute myocardial infarction and ischemic stroke [114]. KardioPro participation was associated with significantly increased physician costs (by 33%), reduced hospital costs (by 19%), and reduced pharmaceutical costs (by 16%) [115].

In the UK, the Quality and Outcomes Framework, established in 2004, rewards PCPs for the proper management of the most common chronic diseases, including CVDs through the pay-for-performance scheme. While the financial incentives have proven effective in increased screening, the overall benefits of this scheme remained limited [116]. However, a similar approach, with financial (and non-financial) incentives, holds the potential to motivate PCPs to rigorously identify CV risk factors and manage them more aggressively.

Between 1988 and 1993, close to 6000 people with at least one CV risk factor were enrolled in the Physical Activity on Prescription program initiated in the city of Sollentuna in Sweden. Two decades later, this population presented with lower risk of CV events (12%), CV deaths (21%) and all-cause deaths (17%), compared to the population of Stockholm [117]. This underscores the importance of health interventions at the primary care level and how early intervention results in long-term protection against CVDs. In 2001, Weinehall et al. reported on the first 10 years of the Norsjö community intervention program in Northern Sweden, which aimed at providing grounds for CVD prevention. Health screening and counselling resulted in major impact on dietary habits and were well received by the community; highlighting the possibility of creating local/regional programs that cater to the specific needs of a community in terms of CV health. The Västerbotten Intervention Program was designed and evaluated in Norsjö and then extended to other Swedish regions. The 10-year evaluation of the program showed significantly greater reductions in cholesterol and blood pressure levels in Norsjö, resulting in 36% reduction in CV mortality, compared to another Northern Sweden city (with 1% reduction in CV mortality) [118]. Importantly, such programs aim to increase the rate of health checks and to decrease the gap between socio-economically privileged and underprivileged communities. This program also allowed the creation of a massive population-based database and, once again, reemphasized the role of primary care centers in CVD prevention.

5.2. The establishment of a CVD registry in Saudi Arabia

The current practice in Saudi Arabia is governed by the latest US and European guidelines. These data might not always be applicable to our population in Saudi Arabia. In order to improve the CV healthcare outcomes in Saudi Arabia, one needs to understand the population better by collecting our own data and launching a continuous CV health registry. The registry should have multiple tracks focusing on risks, prevention, diagnoses, management and outcomes of CVDs. This initiative will also serve in identifying unmet needs, improving public health outcomes and will lead to more specific Saudi-based guidelines. Such data will also serve as grounds for updating national guidelines on CV prevention and management. The success of such an initiative will heavily depend on government's support; in terms of mandatory data entry, data verification, data collection and analysis along with the necessary funding. Setting up registries will require financing for platform design, expert consultation, information technology support for the creation and maintenance of the database, as well as data management and analysis. The ABSHER platform launched in 2015 by the Saudi Health Council ensures a secure mass collection of health-related data, in an attempt to extract insights and advance decision-making [46]. Such

self-reported platform can help in large scale epidemiological studies along with the help of the National Heart Centre, which could oversee the questionnaire design, data collection and analysis in the field of CV medicine. Recently, the Tawakkalna and the Sehhaty platforms have been launched in response to the Corona Virus Disease 2019 caused by SARS-CoV-2 (COVID-19) pandemic. The Tawakkalna application was used to issue movement permits during curfew, to report violations of rules to curb the spread of the virus, and to inform on users' health status and now being widely used to ensure vaccinations compliance [119]. The Sehhaty application makes health information and medical e-services, provided by different health organizations in Saudi Arabia, accessible to users. These services include vital signs updates, tracking prescribed medications, retrieving and sharing sick leaves, booking appointments for COVID-19 vaccination, promoting a healthy lifestyle, etc. [120] These platforms and others could be channeled towards healthcare services beyond COVID-19, once the pandemic has completely subsided.

6. The way forward in CV health

6.1. Global recommendations

In line with the Action Plan of the World Health Organization for the prevention and control of noncommunicable diseases, stakeholders involved in the fight against CVDs could aim for the following specific targets: increase in physical activity, reduction in hypertension, lipid management, reduction in diabetes and obesity rates, decrease in salt/sodium intake, tobacco use control, promote healthier food products through policy and awareness campaigns, and mobilization of funds and resources to implement health-directed programs and need assessment activities [121].

6.2. Measures that can be undertaken in Saudi Arabia

Based on the above-mentioned recommendations from the WHO, specific initiatives can be undertaken in Saudi Arabia. Task forces at the MOH could be created to design, execute and oversee the implementation of the below actions.

- Smoking ban, including electronic cigarettes and smokeless tobaccos; as well as promotion of smoking cessation programs
- Rigorous control of salt content and consumption in diet
- Promote physical activity by enhancing accessibility and affordability of sports venues, focusing on mandatory physical education at schools and universities, developing community and sports centers across the country, organizing large-scale community sporting events for the public to participate in
- Develop an action for early detection and treatment of dyslipidemia, with a particular focus on LDL-cholesterol (Screening programs)
- Make regular health checks mandatory for all adults of all ages to make sure screening is done appropriately per guidelines
- Provide primary care physicians all the resources they need (time, support, training, etc.) to focus on high quality prevention programs
- Enforce quality measures on CV risk factors management
- Establish a health literacy committee at the MOH to promote patient and community education on health matters, disease prevention, early symptoms reporting, adherence to treatment; with a dedicated task force for CV health
- Establish national registries that will promote the development of Saudi-specific guidelines, which will aim to create the best healthcare quality to our population.

7. Concluding statements

In conclusion, Saudi Arabia, like other industrialized countries, is dealing with a great CVDs burden attributed to aging population and the rise of CV risk factors. This pattern is exacerbated by increasing rates of obesity and unhealthy lifestyle. However, with the current trajectory of the health reform in Saudi, a collaborative approach is needed to address CV risk factors and reduce the burden of CVD in the country. Focus should be shifted now to prevention on multiple levels, including individual educational and awareness programs, community programs as well as well-established primary care clinics that are widely accessible and offer high quality screening and management programs. These programs will create a cost-effective approach and will lower the morbidity and mortality associated with CVDs.

Author contribution

Conception and design of Study: AAT, RFAB. Literature review: AAT, RFAB. Acquisition of data: AAT, RFAB. Drafting of manuscript: AAT, RFAB. Revising and editing the manuscript critically for important intellectual contents: AAT, RFAB. Data

preparation and presentation: AAT, RFAB. Supervision of the research: AAT, RFAB. Research coordination and management: AAT. Funding for the research: AAT.

Conflict of interest

Authors declare no conflict of interest.

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