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RESEARCH ARTICLE

DIABETIC FOOT AMONG INDIVIDUALS WITH DIABETES IN SAUDI ARABIA: A COMPREHENSIVE REVIEW

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Abstract

Diabetic foot ulcers (DFUs) pose a significant health challenge globally, particularly in Saudi Arabia, where the prevalence of diabetes is among the highest in the world. This comprehensive review explores various aspects of DFUs among the Saudi population, including prevalence, risk factors, complications, management strategies, socioeconomic factors, and healthcare expenditure. The review highlights the significant impact of DFUs on healthcare costs and quality of life, emphasizing the need for effective prevention and treatment strategies. It discusses challenges and barriers in DFU management and identifies advances and innovations in care, such as multidisciplinary clinics, telemedicine, and research into novel therapies. Recommendations include implementing educational programs, capacity-building initiatives for healthcare professionals, cost-of-illness studies, and advocacy for public health policies prioritizing diabetic foot care. Overall, this review underscores the importance of tailored approaches to managing DFUs in the Saudi population to improve outcomes and reduce the burden of this debilitating complication of diabetes.

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Introduction:-

Diabetes mellitus (DM) is a complex and chronic metabolic disorder characterized by the body's inability to effectively regulate blood glucose (or blood sugar) levels. This dysfunction arises from either a lack of insulin production (type 1 diabetes; T1DM) or insulin resistance, where cells fail to respond adequately to insulin (type 2 diabetes; T2DM). In addition to the two main types, there are other less common forms of diabetes, including gestational diabetes, which develops during pregnancy, and latent autoimmune diabetes in adults (LADA), which shares characteristics of both T1DM and T2DM. T1DM typically presents in childhood and has a strong genetic predisposition. In contrast, T2DM, the more prevalent form, is often associated with factors such as obesity,

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sedentary lifestyle, and advancing age, although it can also affect children and younger adults (1–3). Regardless of the specific type, uncontrolled diabetes can lead to a range of serious health complications, affecting the eyes, kidneys, nerves, and cardiovascular system.

The global burden of diabetes has reached alarming proportions, solidifying its position as a leading public health challenge (1,4,5). Recent decades have witnessed a dramatic surge in diabetes prevalence across developed and developing nations (6–8). Approximately 10% of the global population aged 20 to 79 years, totaling 537 million individuals, currently live with diabetes. Projections indicate that these figures will rise to 643 million by 2030 and 783 million by 2045(9). In 2021, diabetes was responsible for approximately 6.7 million deaths. Financially, diabetes accounted for at least USD 966 billion in health expenditures in 2021, marking a 316% increase over the last 15 years. Additionally, impaired glucose tolerance places an estimated 541 million people at elevated risk of developing T2DM(10–12)

With the highest estimated prevalence of diabetes in the Middle East and North Africa region at 18.1%, Saudi Arabia was found to be among the top ten countries with the highest prevalence of T2DM worldwide(12). The International Diabetes Federation(IDF) projects that by 2035, the incidence in the Gulf region alone will have increased by about 20% (Saudi Arabia: 24.5%; Kuwait: 23.2%; the United Arab Emirates [UAE]: 19.4%)(12). The increase in diabetes cases has a significant impact on the economy. It is estimated that the cost of diabetes-related treatment in Saudi Arabia was 17 billion SAR in 2014. Moreover, the yearly public healthcare spending on people with diabetes is expected to be ten times higher than that of those without the disease (13).

One of the major complications of diabetes that affects 18.6 million individuals globally each year, including 1.6 million in the US, is diabetic foot ulcers (DFU). In patients with diabetes, these ulcers are linked to a higher risk of death and account for 80% of lower extremity amputations. High blood sugar, peripheral vascular disease, and neuropathy—damage to the nerves—are some of the variables that contribute to the disorder(14,15). In Saudi Arabia, 3.3% of diabetic patients were found to have DF problems (16). Among DF patients, vasculopathy was observed in 33.1% (17). Peripheral artery disease (PAD) ranks as the third most common vascular complication among Saudi patients, with a prevalence rate of 2.41%, following cerebral vascular disease (10.2%) and coronary artery disease (23.6%). Moreover, among DFU patients, those with foot ulcers have a prevalence of PAD at 30%, while those with amputations show a higher prevalence at 54% (17).

A recent study at a Saudi Arabian tertiary care institution revealed that the total cost of managing DFU over ten years amounted to 6,618,043.3 Saudi Riyals (SAR), equivalent to 1,764,632.68 US Dollars (USD). This study estimated the annual cost of managing DFU at 661,804.3 SAR (176,481.2 USD), translating to 6,684.9 SAR (1,782.6 USD) per patient year. These figures underscore the considerable financial burden of DFU on healthcare resources and were derived from a patient sample at a single institution (18). Outpatient topical treatments represent approximately 51% of the total cost of DFU management. However, due to the prolonged healing process associated with DFU, surgical intervention may offer a more cost-effective solution. In cases requiring surgical management, surgical intervention accounts for about 95% of the total cost, with antibiotics constituting approximately 4% of the overall expenditure (18).

This review comprehensively examines various dimensions of diabetic foot (DF) complications within the Saudi population. It delves into multiple facets, such as the prevalence and incidence of the condition, associated risk factors, diagnostic methodologies, effectiveness of treatment strategies, socioeconomic influences, avenues for future research, recommendations for optimal approaches, and the consequential impact on both healthcare expenditure and quality of life. By addressing these diverse dimensions, the review seeks to advance the understanding and management of DF complications in Saudi Arabia, ultimately aiming to improve healthcare outcomes and enhance the well-being of affected individuals.

Methodology:-

Our research entailed a thorough exploration of databases, including Medline (via PubMed), Scopus, and Web of Science, employing a set of targeted keywords such as "Saudi Arabia," "Prevalence," "Diabetes," "Diabetic Foot," "Management," "Socioeconomic Factors," and "Healthcare." Inclusion criteria encompassed studies concentrating on the Saudi population, published in English, and comprising research endeavors spanning clinical trials, observational studies, systematic reviews, and meta-analyses, all investigating diverse facets of DF.

Epidemiology of Diabetes in Saudi Arabia

According to the World Health Organization (WHO), Saudi Arabia has the second-highest diabetes prevalence in the Middle East and the seventh-highest worldwide (19). The prevalence of DFU in the IDF Middle East and North Africa Region ranges between 5.0% and 20.0% (12). The prevalence of lower limb amputations (LLA) varied from 0.2% in Saudi Arabia to 60.0% in Jordan, with values often falling below 30.0% (13–16). Studies with sample sizes of fewer than 300 participants indicated higher values for LLA prevalence in this region. These studies might have occurred in specialist clinics or inpatient high-risk settings rather than community settings where one would anticipate a larger sample size (17).

From 2000 to 2011, the number of people aged 20-79 with diabetes increased from 996,700 to 2,759,600. The age-adjusted comparative prevalence of diabetes during this period decreased from 19.6% to 18.7%. In 2021, the number of individuals with diabetes rose to 4,274,100, with a prevalence rate of 20.4%. By 2030, researchers estimate that diabetes will affect approximately 5,631,000 people, with a projected prevalence of 21.4%. They expect that by 2045, the number of individuals with diabetes will further increase to 7,537,300. Diabetes Estimates and Projections in Saudi Arabia (2000-2045) are shown in **Figure 1**.

The IDF reported that in 2021, approximately 4.3 million individuals aged between 20 and 79 years in Saudi Arabia were diagnosed with diabetes, and researchers suggest that the number of diagnosed diabetes cases will reach 5.5 million by 2030. Notably, about 43.6% of people with diabetes in Saudi Arabia remain undiagnosed, and the percentage of diabetes-related deaths among individuals under 60 years old is almost 13.8% (12). Among individuals aged 20 to 79, women are anticipated to experience a slightly lower prevalence of diabetes (10.2% compared to 10.8% in men). The prevalence (%) estimates of diabetes by age and sex, IDF Middle East and North Africa Region in 2021 are shown in **Figure 2**,

Risk Factors and complications of DF

Complications stemming from diabetes can be broadly categorized into two types. Macrovascular problems, involving long-term damage to major blood vessels, contribute to cardiovascular disorders, while damage to small vessels can lead to neuropathy, blindness, and kidney-related diseases (20,21). Diabetic neuropathy, affecting approximately 30% of adults with diabetes, particularly those over 50, damages peripheral nerves, increasing the risk of DFU and lower-extremity amputations (22,23). DFU, arising from multiple factors including peripheral neuropathy, atherosclerotic peripheral artery disease, and mechanical foot architecture modifications, is a significant concern in Saudi Arabia, with a prevalence rate of approximately 2.3% (24,25). Its occurrence is influenced by various factors such as reduced joint mobility, foot abnormalities, pressure or trauma, and peripheral vascular or neuropathic diseases (26).

The prevalence of DFU complications, notably infection, poses a significant risk, with about 25% of DFUs becoming infected and up to 20% of infected cases resulting in amputation (27,28). A cross-sectional study conducted at a tertiary center in Saudi Arabia found that over two-thirds of DFU patients presented with cellulitis and/or osteomyelitis, with a significant correlation between traditional remedies usage and higher Wagner scale grades and osteomyelitis. Furthermore, the study noted the chronic nature of these ulcers, with the mean duration of open wounds being 206.9 days, underscoring the urgency of effective management to prevent progression to gangrene and subsequent amputation (29,30).

In Riyadh, a study revealed that primary care providers lack optimal knowledge about diagnosing and managing DF infections, with only 53.9% performing a probe-to-bone test on DF patients with open wounds, indicating a gap in diagnostic practices (16). Another study highlighted a general lack of awareness among healthcare workers, diabetic patients, and their relatives in Saudi Arabia regarding DFUs, emphasizing the need for improved knowledge dissemination to facilitate early diagnosis and treatment (31). The impact of DFUs extends beyond physical health, significantly affecting patients' quality of life. Factors such as age, gender, education, occupation, smoking habits, duration of diabetes, and associated complications influence patients' perceived health-related quality of life, highlighting the multidimensional burden of DFUs (32).

While peripheral neuropathy is a common risk factor, specific factors contributing to DFU development include genetic predisposition, advancing age, obesity, sedentary lifestyle, and unhealthy dietary habits like smoking (33,34). Addressing these modifiable risk factors through lifestyle modifications and interventions is crucial for preventing DFU occurrence and reducing associated complications.

Management of DFU

To effectively treat DFU, a multifaceted approach is necessary, encompassing various interventions aimed at promoting wound healing and preventing complications. Offloading the wound is paramount, as evidenced by studies (35,36). This involves using regular saline or comparable dressings to maintain wound moisture, along with debridement when necessary. Additionally, antibiotic treatment may be required in cases of osteomyelitis or soft tissue infection, either with or without surgery (37,38). Optimal blood glucose management and assessment and treatment of peripheral arterial insufficiency are also crucial components of DFU management (39). In cases where nonsurgical offloading therapy fails to improve ulcer healing in neuropathic plantar ulcers, more invasive procedures such as joint arthroplasty, Achilles tendon lengthening, or metatarsal head resection may be considered (40,41). While adjunct therapies like recombinant growth factors or hyperbaric oxygen may be beneficial in some cases, caution is advised, especially in the presence of arterial insufficiency (42–44).

Healthcare professionals tasked with treating diabetic patients with ulcers often face challenging decisions regarding treatment strategies. Balancing the need for invasive procedures to salvage limbs against the risks associated with aggressive management in high cardiac-risk patients requires careful consideration (45,46). Legal implications also underscore the importance of prompt diagnosis and thorough treatment of DFUs to prevent adverse outcomes (47,48).

The International Working Group on the Diabetic Foot (IWGDF) plays a pivotal role in developing evidence-based guidelines for the prevention and treatment of DFU-related issues (49). The IWGDF infection guidelines emphasize the importance of prompt and appropriate management of severe infections. In cases of severe infection, prompt assessment for surgical intervention is crucial to remove necrotic tissue, alleviate compartment pressure, and drain abscesses. Examination for PAD is also essential, as immediate medical attention and revascularization may be warranted post-infection control. Broad-spectrum empirical antibiotic therapy via parenteral administration is recommended to combat common gram-positive and gram-negative bacteria, including obligatory anaerobes. Subsequent adjustments to the antibiotic regimen should be made based on culture and sensitivity results and clinical response to empirical therapy. Antibiotic therapy for soft-tissue infections typically spans one to two weeks. However, prolonged treatment may be necessary for severe illnesses or slow-clearing infections. In cases of osteomyelitis, where conservative antibiotic treatment is preferred over incision and drainage, treatment duration should be carefully considered. For minor soft tissue infections with superficial ulcers, prompt removal of necrotic tissue and calluses is essential. Initiation of oral antibiotics without delay is recommended to address common pathogens like *Staphylococcus aureus* and β -hemolytic streptococci, unless alternative infections are suspected (49,50). The IWGDF 2023 Risk Stratification System and corresponding foot screening frequency are shown in **Table 1**.

A holistic, team-based approach is essential for the successful prevention and treatment of diabetes-related foot conditions. Annual foot exams for diabetic patients, education on risk reduction strategies, and prompt treatment of infections or ulcers are key components of organized foot care. Access to podiatric care, appropriate footwear, and insoles is critical for mitigating risks (51,52).

The healing of foot ulcers is significantly influenced by ischemia in the lower extremities. Recommendations from the intersocietal IWGDF stress the importance of considering vascular imaging and revascularization in individuals with compromised blood flow (50). Immediate evaluation and management are advised for patients with ankle pressure less than 50 mm Hg or ABI less than 0.4, or in cases of T_{cp}O₂ less than 25 mmHg or toe pressure less than 30 mmHg. Revascularization aims to restore blood flow to the affected area, ideally through the artery supplying the injured region. However, careful consideration of individual factors, such as patient co-morbidities and local expertise, is necessary when selecting a revascularization procedure. Post-surgery, perfusion measurement is used to assess the success of revascularization. It is important to emphasize lifestyle modifications and pharmacological interventions to lower cardiovascular risk associated with PAD in diabetic patients, such as smoking cessation, blood pressure and cholesterol management, and the use of certain medications like anti-platelets, SGLT2-inhibitors, or GLP1-agonists.

Offloading is a critical aspect of treating foot ulcers induced by heightened mechanical stress, as outlined in the IWGDF Offloading guidelines (53). For neuropathic plantar ulcers, healthcare providers recommend using a non-removable knee-high offloading device such as a total contact cast or a detachable walker, fitted by a professional.

In cases where a non-removable device is not feasible or tolerated, a removable knee-high or ankle-high offloading device can serve as an alternative. Consistent wear of detachable devices is essential to reap their benefits.

Diabetes-related amputations pose a substantial challenge for the Saudi Ministry of Health. A 2018 Saudi statistical yearbook reported a concerning number of cases, with 1,280 in diabetic males and 765 in diabetic females (54). Addressing this issue necessitates a comprehensive assessment of knowledge, awareness, and practices related to DFU among healthcare staff, patients, and their families (31). Implementation of digital health solutions, such as patient-owned wound surveillance applications, can enhance DFU care by promoting patient engagement, monitoring, and communication with healthcare providers (55). Additionally, novel approaches like immunomodulatory hydrogels show promise in improving wound healing outcomes by addressing hyperglycemia-induced inflammation and reactive oxygen species elevation (56). Effective management of DFU requires addressing healthcare access inequities and social deprivation. A narrative review underscores the intricate interplay between healthcare access, DFU risk, and outcomes, emphasizing the necessity of a multimodal approach to tackle these challenges (57).

Advancements in DFU Management in Saudi Arabia

Saudi Arabia, like many countries worldwide, faces significant health challenges associated with DFUs. However, recent advancements in DFU care, including innovative medications and methods, offer hope for improving patient outcomes. In line with global trends, DFUs remain a major health concern in Saudi Arabia. Yet, the introduction of novel therapies and approaches has led to significant progress in their management. Specialized multidisciplinary clinics dedicated to DFU therapy have emerged, bringing together podiatrists, vascular surgeons, endocrinologists, and infectious disease specialists to provide comprehensive care (29).

The adoption of advanced wound dressings, which offer mechanical protection, bacterial control, and moisture maintenance, has become increasingly popular, creating optimal conditions for healing. Additionally, the utilization of negative pressure wound therapy (NPWT) has gained traction and demonstrated effectiveness in DFU care (72). Some Saudi hospitals now offer hyperbaric oxygen therapy (HBOT), a treatment involving the inhalation of pure oxygen under pressure, which has proven efficacy (73).

The transformation of DFU management in Saudi Arabia has been further facilitated by the growth of telemedicine. Teleconsultations allow patients to receive professional advice and treatment remotely, eliminating the need for in-person hospital visits. Healthcare professionals can remotely monitor patients' wound healing progress, blood sugar levels, and other vital health indicators in real-time, enabling timely adjustments to treatment plans when necessary (74). Tele-education programs equip patients and caregivers with essential knowledge and skills for effective DFU management, thereby reducing complications and the need for amputations (29).

Saudi Arabia is actively engaged in research projects exploring novel therapies such as growth factors and stem cell therapy, as well as studies investigating the underlying causes and consequences of DFUs. Through these coordinated initiatives, Saudi Arabia aims to enhance patient care and outcomes nationwide, refining its DFU management strategy for the benefit of all (31,72).

Challenges and Barriers

Despite significant advancements in diabetes treatment over the past two decades, the management and treatment of DFU still face major barriers within the healthcare system. Addressing these challenges requires careful planning of teaching programs and access points to improve healthcare delivery and reduce disparities (58).

At the individual level, lack of knowledge about DF issues and delays in seeking medical help pose significant obstacles. Patients need to be educated about the importance of prompt medical attention for foot injuries, as diabetes increases the risk of infection and amputation. Moreover, the high costs associated with DFU care highlight the need for comprehensive coverage by safety net insurance providers (59,60).

The patient-provider relationship plays a crucial role in DFU therapy, but challenges in finding suitable healthcare providers and disruptions in continuity of care hinder optimal treatment. Solutions such as increasing the employment of community health workers and improving healthcare assessments can help address these gaps (61,62).

Access to medical equipment is another challenge, with deficiencies in medical supply firms often leading to difficulties in obtaining necessary supplies. Creating partnerships between pharmacies and healthcare providers to provide medical equipment may improve access, especially considering the frequent interaction between patients with diabetes and pharmacists (63,64).

Effective preventative treatment by primary care physicians is essential for limb salvage and the prevention of DFUs. The American Diabetes Association recommends regular foot examinations for diabetic patients at every doctor's appointment and a thorough foot inspection once a year at the latest, emphasizing the importance of identifying risk factors for DFUs (65). Preventive foot care, including self-foot inspection, professional foot examinations, and the use of suitable footwear, should be emphasized to both patients and medical professionals (65).

Furthermore, establishing a defined procedure and care route for initial DFU care is crucial to prevent misdiagnoses and delays in treatment. Educating patients and clinicians about standard protocols is essential to minimize delays in seeking care and improve outcomes (66).

In Saudi Arabia, like many other nations, several challenges hinder the prompt and effective treatment of individuals with DFUs. These challenges include a lack of hospitals, restricted access to specialist care, and insufficient knowledge about DFUs among patients and healthcare professionals (67,68). These factors contribute to delays in diagnosis and treatment, increasing the risk of complications and amputations. Addressing these issues requires attention to insurance and policy matters, alongside efforts to strengthen the healthcare infrastructure. Establishing specialist DF care centers and implementing national guidelines and protocols are essential for providing high-quality care (69). Public education programs are crucial for raising awareness about diabetes and foot care, emphasizing the importance of early ulcer detection (70). Additionally, ensuring comprehensive insurance coverage for podiatry, wound care, and specialty footwear is essential to enable patients to access necessary treatments. Clear reimbursement policies are also necessary to adequately compensate healthcare providers participating in DFU management (71).

Conclusions and Recommendations:-

In Saudi Arabia, DFUs present a significant health concern, especially given the higher prevalence among diabetes patients, often attributed to genetic predispositions, familial history of diabetes, and an aging population. Multidisciplinary care approaches, including sophisticated wound management techniques and specialized clinics, have emerged as crucial components in addressing DFUs. These efforts underline the importance of comprehensive care tailored to the specific needs of DFU patients, reflecting a growing awareness of the complexities involved in managing this condition.

Furthermore, the integration of telemedicine into DFU management signifies a promising advancement, enabling remote consultations and monitoring that enhance accessibility to specialized care, particularly in regions with limited healthcare infrastructure. This innovation not only facilitates timely interventions but also empowers patients and caregivers with essential knowledge for effective DFU management. Additionally, ongoing research initiatives, including investigations into novel therapies and advanced wound care products, demonstrate a commitment to continuously improving DFU treatment outcomes.

Looking ahead, future research endeavors in Saudi Arabia should prioritize several key areas to further enhance DFU management. This includes evaluating the effectiveness of educational programs aimed at raising public awareness about DF and preventive measures. Moreover, initiatives to strengthen healthcare professionals' expertise in DFU screening and management, alongside capacity-building efforts in primary healthcare settings, are essential for optimizing patient outcomes and reducing the incidence of DFU-related complications.

Technological advancements, such as molecular-level assessments and innovative therapy modalities, hold promise for transforming DFU care. By exploring cutting-edge technologies and treatment strategies, researchers aim to address the complex challenges associated with DFUs effectively. Additionally, community-based interventions and advocacy for public health policies prioritizing DF care are vital for reducing the prevalence of DFUs and improving the overall quality of life for individuals with diabetes in Saudi Arabia.

In summary, the management of DFUs in Saudi Arabia reflects a multifaceted approach encompassing multidisciplinary care, telemedicine integration, ongoing research initiatives, and community-based interventions. These efforts underscore a concerted commitment to enhancing DFU management strategies, with a focus on improving patient outcomes and reducing the burden of DFU-related complications on individuals and healthcare systems alike.

Table 1:- The IWGDF 2023 Risk Stratification System and corresponding foot screening frequency (75).

Risk category	Ulcer Risk	Definition	Suggested follow-up
0	Very low	No LOPS, no PAD, no deformity	Once a year
1	Low	LOPS or PAD	Once every 6-12 months
2	Moderate	LOPS + PAD, or LOPS + foot deformity or PAD + foot deformity	Once every 3-6 months
3	High	LOPS or PAD, and one or more of the following: - history of a foot ulcer - a lower-extremity amputation (minor or major) - end-stage renal disease	Once every 1-3 months

LOPS = Loss of Protective Sensation; PAD = Peripheral Artery Disease

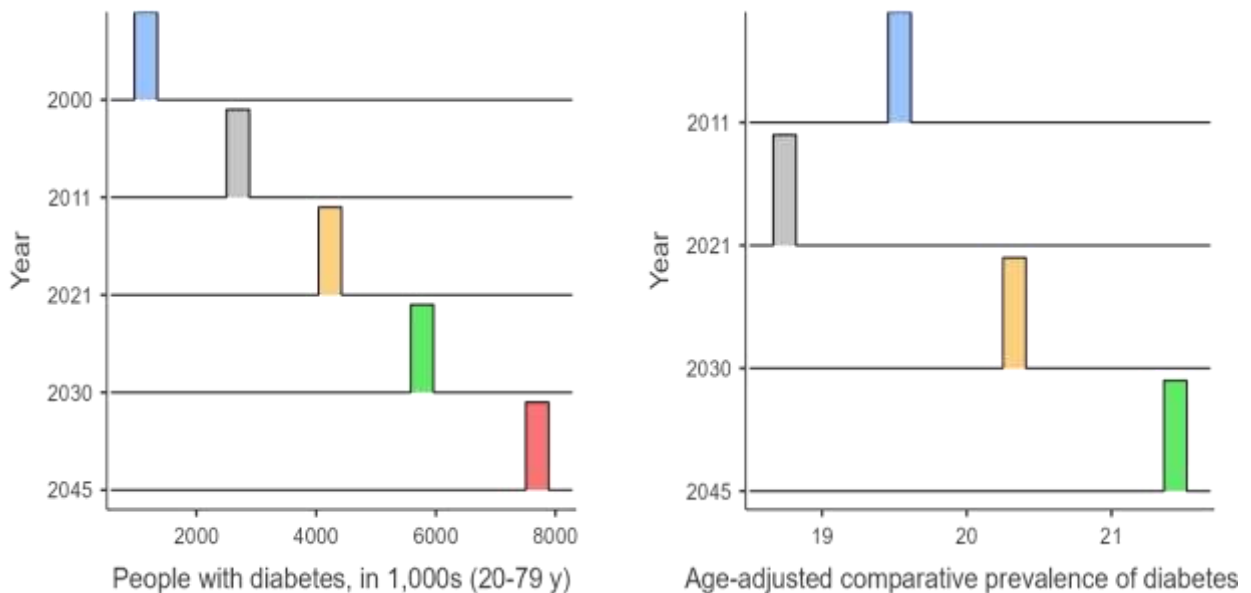


Figure 1:- Diabetes Estimates and Projections in Saudi Arabia (2000-2045) (12).

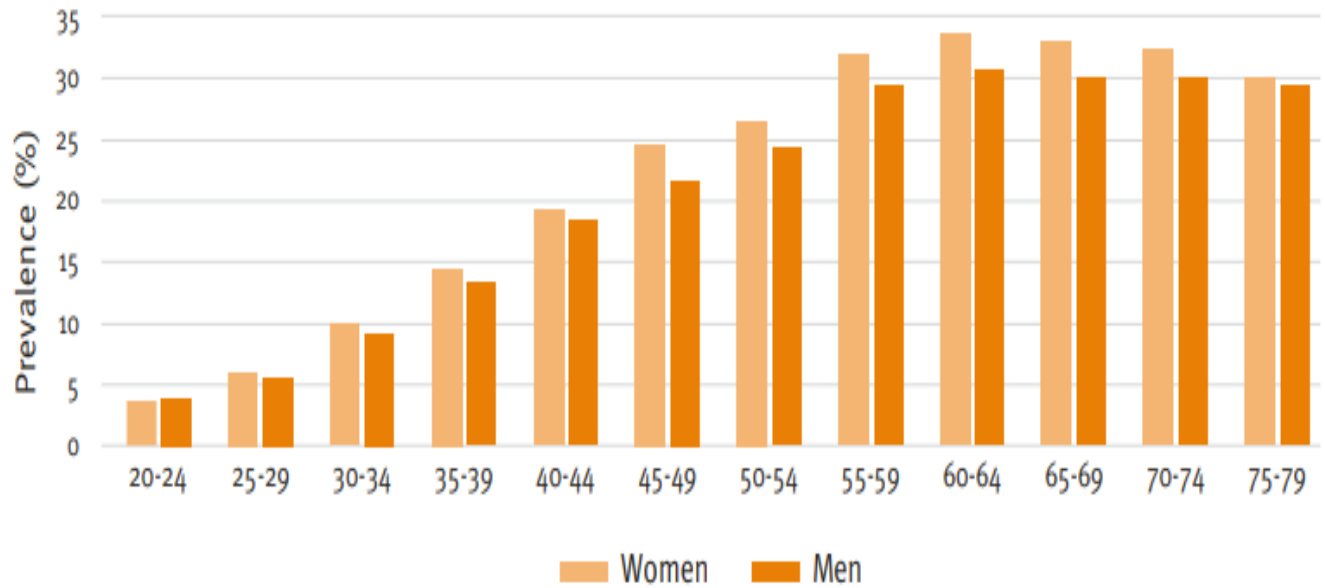


Figure 2:-Prevalence (%) estimates of diabetes by age and sex, IDF Middle East and North Africa Region in 2021(12).

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