Keywords: Diabetes mellitus; COVID-19; telemedicine; public health; health-system resilience

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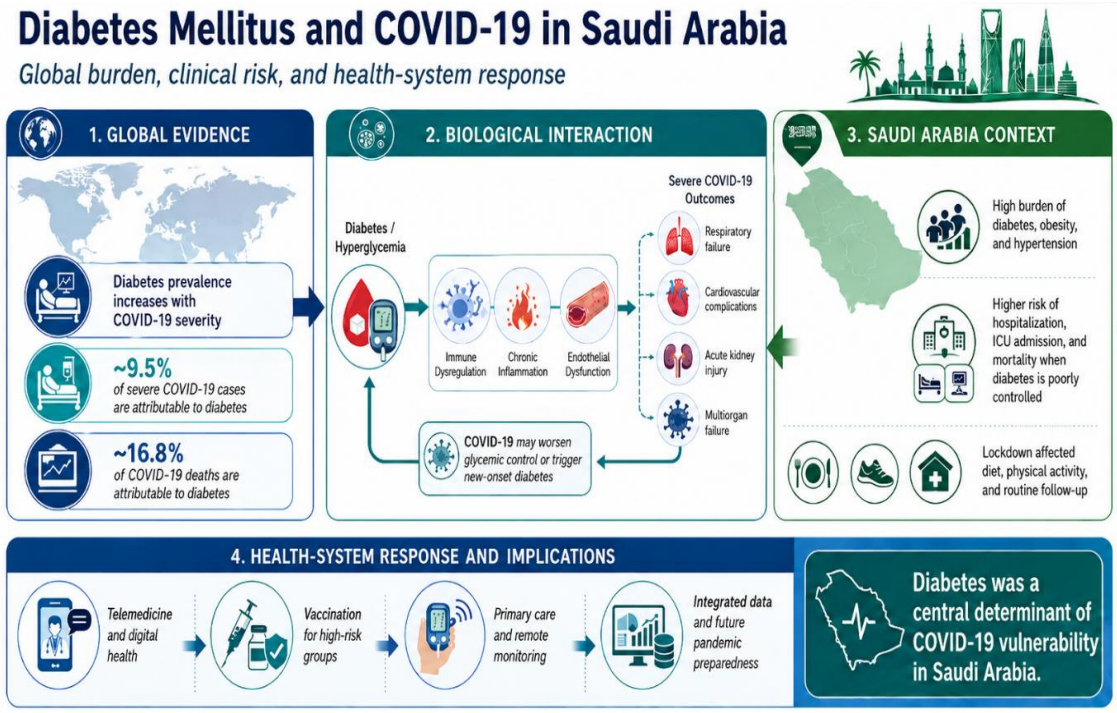
Diabetes Mellitus and COVID-19 in Saudi Arabia: Epidemiology, Clinical Risk, and Health System Impact

Abstract

Diabetes mellitus and COVID-19 have converged as important public health challenges. Diabetes has been consistently associated with severe infection, hospitalisation, intensive care admission, and mortality. This relationship is particularly important in Saudi where diabetes, obesity, hypertension and metabolic syndrome are highly prevalent. This narrative review made evidence from systematic reviews, meta-analyses, cohort studies, clinical studies from Saudi Arabia, and public health worldwide literature on the epidemiology of diabetes, COVID-19 outcomes, glycaemic control, complications, vaccination, telemedicine, and health-system response. Evidence from around the world points to an association between diabetes and an increased risk for severe COVID-19, particularly in the context of poor glycaemic control, obesity, hypertension, cardiovascular disease or chronic kidney disease. Diabetes also is reported as one of the most common comorbidities among hospitalised COVID-19 patients in Saudi studies with worse outcomes reported in patients with uncontrolled diabetes and multimorbidity. The pandemic has also impacted diabetes care through reduced physical activity, changes in diet, psychological stress and lack of access to routine follow-up. In response, Saudi Arabia expanded telemedicine, digital health platforms, national guidance, and vaccination priority for high-risk groups. These findings suggest that diabetes was a prevalent comorbidity during the COVID-19 pandemic in Saudi Arabia, and a major factor determining vulnerability. To be ready for the future, diabetes care must be integrated into emergency planning, through stronger primary care, remote monitoring, interoperable health data, and population-level risk surveillance.

Graphical Abstract



1. INTRODUCTION

The emergence of two big global health challenges, diabetes mellitus (DM) and coronavirus disease 2019 (COVID-19), has created a huge strain on health systems across the world. Diabetes is a chronic metabolic disease characterised by persistent hyperglycemia. Currently, approximately 537 million adults are living with diabetes worldwide and this number is projected to rise to 783 million by 2045 [1]. COVID-19 has also created an unparalleled global burden with hundreds of millions of confirmed infections and millions of reported deaths worldwide, but accurate global case and death counts are generally obtained from the WHO surveillance [2], [3]. The combination of these conditions has increased morbidity, mortality and long-term health consequences, creating a syndemic interaction that merits targeted scientific and clinical attention. In addition, there is growing high quality evidence to suggest diabetes is an independent risk factor for severe COVID-19 illness including hospitalisation, admission to intensive care unit and death [4] Systematic reviews and meta-analyses demonstrate that the prevalence of diabetes increases with the severity of COVID-19, affecting 28–35% of critically ill or deceased patients [5]. Diabetes is estimated to account for about 9.5% of severe cases and 16.8% of deaths worldwide from COVID-19, showing its impact on the population [5], [6]. Recent meta-analyses further confirm that patients with diabetes have a significantly higher risk of severe disease compared to patients without diabetes [7]. These findings support the view that diabetes is not only a comorbidity but an important determinant of COVID-19 outcomes. Diabetes contributes to COVID-19 because of the commonalities in immune and metabolic dysfunction. Chronic hyperglycemia can impair innate and adaptive immunity including neutrophil chemotaxis, phagocytosis and T-cell function which can all weaken antiviral defence [8]. The disease is also associated with chronic low-grade inflammation, endothelial dysfunction, and oxidative stress, which may predispose to exaggerated inflammatory responses in severe COVID-19 [7], [8]. SARS-CoV-2 infection may further aggravate these abnormalities by promoting immune dysregulation and inflammatory pathways involving cytokines such as interleukin-6 and tumour necrosis factor-α[8], [9]. Emerging evidence also suggests a bidirectional relationship, in which COVID-19 may precipitate new-onset diabetes or worsen existing glycemic control[10], [11]. Beyond individual mechanisms, the interaction between diabetes and COVID-19 has important population-level implications, especially in regions with a high burden of metabolic disorders. The Middle East, and Saudi Arabia in particular, represents a high-risk setting because of the high prevalence of diabetes and related cardiometabolic disease. National and regional evidence links this burden to rapid urbanization, sedentary lifestyle, obesity, dietary transition, and possible genetic susceptibility [12]. As a result, people with diabetes form a large vulnerable subgroup within the Saudi COVID-19 population and contribute substantially to hospitalization and adverse outcomes [13]. Early Saudi evidence also indicates that diabetes was among the most common comorbidities reported in patients with COVID-19, consistent with global findings [13]. The COVID-19 pandemic in Saudi Arabia directly affected the infection but also had a profound impact on diabetes management and the delivery of healthcare. Lockdowns and changes in healthcare systems were related to reduced physical activity, dietary changes, psychological stress and limited access to routine care, all of which can negatively impact glycaemic control [14]. The COVID-19 pandemic led health care providers to rapidly adopt telemedicine and digital health solutions to ensure continuity of care, revealing opportunities and shortcomings in the management of chronic disease [11]. These changes imply that the burden of COVID-19 in people with diabetes is multifactorial, including biological vulnerability, behavioural change, and healthcare system resilience. Some studies discussed the clinical outcomes, lifestyle modifications, and adaptations in health care during the pandemic [12], [15], [16], [17]. However, there is still a need for an integrated review with epidemiological patterns, clinical outcomes, and health system responses in the Saudi context. This review discusses the association between diabetes mellitus and COVID-19 in Saudi Arabia with a special focus on epidemiology, clinical outcomes, and the impact on diabetes care and healthcare services.

2. EPIDEMIOLOGY OF DIABETES IN SAUDI

Saudi Arabia is among the countries with a high burden of diabetes, but estimates vary depending on criteria for measurement, age structure, sampling methods and diagnostic definitions. The International Diabetes Federation estimated that in 2024, 23.1% of adults in Saudi Arabia would have diabetes, which corresponds to around 5.34 million people [18], [19]. The headline figure should be treated with caution, as Saudi and international estimates are not directly comparable. Some estimates are based on measured fasting glucose or medication use, others on modelled adult prevalence, and older Saudi studies often used self-report or region-specific sampling. This methodological heterogeneity explains why estimates of diabetes in Saudi Arabia may differ from one reputable source to another [12]. Saudi Arabia's diabetes prevalence has risen from modest levels in earlier decades to one of the highest burdens in the region. Earlier and recent reviews link this increase to urbanization, dietary change, reduced physical activity, obesity, and the insulin-resistance syndrome [12]. A systematic review and meta-analysis of observational studies found the pooled prevalence of type 2 diabetes mellitus in Saudi Arabia to be 16.4% from 2000 to 2020, indicating a persistently high burden over the last two decades[7], [12], [20]. Type

2 diabetes accounts for most diabetes cases in Saudi Arabia, as in most adult populations. However, type 1 diabetes mellitus is also epidemiologically important because Saudi Arabia has a high pediatric incidence. A widely cited review reported an annual incidence of approximately 31.4 per 100,000 children under 15 years, placing Saudi Arabia among high-incidence countries globally [21]. Prediabetes is a major public health problem, being a large reservoir for future diabetes. A systematic review in 2025 estimated the pooled prevalence of prediabetes among adult Saudi population to be 24.1% with a higher prevalence among males [22]. Hence, the Saudi diabetes burden is not limited to diagnosed cases but also encompasses a large population already in the glycaemic risk continuum. The age pattern follows biological expectations, generally, but is amplified by the national risk environment. Type 2 diabetes is mainly an adult disease, and its prevalence rises with age, while type 1 diabetes occurs mainly in childhood and adolescence. Sex differences are more complicated. Some data show higher obesity in women, whereas recent prediabetes estimates show higher prevalence of prediabetes among men [22]. These patterns are compatible with sex differences in diabetes risk being determined by a range of factors, including body composition, physical activity, diet, healthcare engagement and detection patterns. Grouping several risk factors is important to understand the high prevalence of diabetes in Saudi Arabia. One big relative factor is obesity. According to a study review, the prevalence of obesity in Saudi Arabia is higher than the global average and is sustained by environmental and behavioural factors such as unhealthy diet and physical inactivity [23]. Diabetes is often accompanied by dyslipidaemia, central obesity, hypertension and insulin resistance which together suggest the metabolic syndrome phenotype, rather than isolated hyperglycaemia [12]. This environmental risk may also be modified by genetic susceptibility. Early Saudi literature often mentioned consanguinity and familial clustering as possible factors contributing to the risk of type 2 diabetes, particularly in the setting of rapid lifestyle change [12], [14]. The evidence remains suggestive, rather than conclusive. Family aggregation is observed but it is difficult to separate the relative contribution of genetic predisposition and shared environment. This difference is important because an overemphasis on genetics may obscure modifiable drivers such as obesity, sedentary lifestyle, and calorie-rich diets. Thus, the epidemiology of diabetes in Saudi Arabia reflects a rapid metabolic transition shaped by genetic and environmental factors. The primary issue in the evidence base is methodological inconsistency with studies varying in age groups, diagnostic criteria, case definitions and methods of sampling. New initiatives such as the Saudi Population Health Observatory may improve the tracking of disease burden, but comparisons between studies should be made cautiously [24].

3. COVID-19 EPIDEMIOLOGY IN SAUDI

Saudi Arabia detected its first confirmed case of COVID-19 in March 2020 [25]. The initial reaction was the swift introduction of public health measures such as travel restrictions, the suspension of mass gatherings, school closures, curfews and phased lockdowns [25], [26], [27]. A Saudi study of the first 18 weeks of the epidemic found that these prevention strategies were associated with control of early case growth and lower case-fatality estimates than those reported in some early international epicentres [28]. The Saudi epidemic was not a single wave. It began with an initial surge in spring 2020, peaked in summer 2020, then went into a lower-burden period in 2021 with expansion of testing, clinical practice and vaccination [25],[26], [28]. In an epidemiological analysis of laboratory-confirmed cases from March 2020 to December 2021 in Saudi Arabia, 549,810 cases were reported with the highest numbers reported in summer months [29]. Same study reported fewer cases and deaths in 2021 than in 2020, perhaps reflecting vaccination, public health measures and improved clinical management [14], [25], [26], [28]. By July 2021, Saudi Arabia reported 506,125 COVID-19 cases and 8,035 deaths, according to a Saudi review focused on diabetes and COVID-19 that used national data [29]. More recent public data show higher cumulative totals by 2024, reflecting continued transmission after the pandemic peak, but exact figures differ by source and update timing [18], [29], [30]. The demographic profile of cases in Saudi Arabia differed from patterns reported in some European and North American settings. During 2020–2021, men made up a large proportion of reported cases, and transmission was concentrated largely among working-age adults rather than only older adults [14], [25], [26], [28]. Nonetheless, severity and mortality still increased with age and medical vulnerability, consistent with global patterns. Comorbidity was a major factor contributing to poor outcomes in Saudi research, with diabetes frequently highlighted. A review of local hospital studies reported diabetes as one of the most common comorbidities among hospitalized COVID-19 patients, with prevalence ranging from approximately 10% to 68% depending on study design, hospital type, and case severity [29]. This wide variation reflects heterogeneity in clinical populations rather than inconsistency in the biological signal. Diabetes becomes more common as cohorts become older, more severe, and more hospital based. The strongest Saudi hospital evidence supports the same direction of association. Among hospitalized patients, diabetes was common and associated with higher mortality, although other factors such as age, heart failure, smoking, renal dysfunction, and severe vitamin D deficiency also influenced risk [29]. This pattern reflects global trends: diabetes rarely occurs alone, but often coexists with obesity, hypertension, cardiovascular disease, and chronic kidney disease, all of which can worsen COVID-19 outcomes [31]. The Saudi COVID-19 epidemic followed the global pattern of multiple waves, declining severity over time, and disproportionate impact on older adults and those with chronic disease. The difference was not the

virus itself, but the context in which it spread. Saudi Arabia's younger population, rapid non-pharmaceutical measures, use of digital surveillance, and early healthcare reorganization likely helped moderate mortality, while the widespread prevalence of diabetes and other metabolic diseases created a large vulnerable group [29].

4. DIABETES AS A RISK FACTOR IN SAUDI COVID-19 PATIENTS

Diabetes was a major comorbidity during the pandemic in Saudi Arabia and was frequently reported among hospitalised COVID-19 patients. The percentage of affected patients indicates that diabetes is more pronounced in older, sicker, and hospital-based populations and not inconsistent in its association with COVID-19 [29]. The clearest Saudi signal is among patients who have been hospitalised. One Riyadh cohort described in the Saudi review reported diabetes in 68.3% of admitted COVID-19 cases. Patients with diabetes had higher mortality than those without diabetes [29]. The same pattern was observed across several hospitals, with diabetes being one of the most common comorbidities among admitted patients and more common in severe cases than in mild or non-ICU groups. This observation aligns with the wider COVID-19 evidence that severe outcomes are not only associated with infection, but also with age, male sex and chronic cardiometabolic conditions [4]. The effect on hospitalisation is particularly important in Saudi Arabia where the prevalence of diabetes is already high. Saudi evidence suggests older adults with diabetes have higher odds of being hospitalised especially when they have higher HbA1c and comorbidities such as hypertension, cardiovascular disease, cerebrovascular disease, chronic lung disease, chronic kidney disease, malignancy or insulin-treated diabetes [29], [32].

This underscores an important clinical message: diabetes increases the risk of hospitalisation, but the risk is amplified in the setting of poor glycaemic control and multimorbidity. Similar trends are seen for ICU admission and death. Internationally, evidence is consistent that diabetes is over-represented among ICU patients and among those with ARDS or death [4]. The Saudi data are consistent with this pattern of more severe symptoms, worse metabolic profile and higher mortality among patients with diabetes, with effect size varying by hospital and study design [29]. Glycemic control seems to be an important risk modifier, perhaps more informative than diabetes status alone. A living meta-analysis showed that higher HbA1c was associated with increased severity and mortality in COVID-19 [31]. In particular, each increase of 20mmol/mol in HbA1c was associated with an increased risk of severe COVID-19, and admission hyperglycemia was also strongly associated with poor outcomes [31]. The Saudi evidence is more limited but suggests the same trend with higher HbA1c associated with higher risk of hospitalisation and worse outcomes [31]. The prevalent concurrent conditions of obesity and hypertension in Saudi Arabia contribute to the association of diabetes with severe COVID-19 through the common metabolic pathway. Diabetes is common in Saudi Arabia and is associated with excess adiposity, high blood pressure, dyslipidaemia and insulin resistance. This clustering may worsen the outcomes of COVID-19 through endothelial dysfunction, chronic inflammation, impaired immune responses and decreased cardiopulmonary reserve [31]. Saudi lockdown and telemedicine studies also show that obesity and hypertension were highly prevalent among diabetic cohorts during the pandemic, indicating that many patients entered the pandemic with a high-risk cardiometabolic profile [33]. Internationally, diabetes is clearly linked to higher risks of severe COVID-19, ICU admission, ARDS, and death [4], [7]. Many studies were single-centre, retrospective, and hospital-based, which may overstate the apparent burden of diabetes. Cohorts also differed in severity, admission criteria, outcome definitions, and adjustment for confounders. This matters because exposures such as insulin use may reflect more advanced diabetes rather than a direct harmful effect of insulin itself [31]. The key clinical message is that diabetes is a significant risk factor for severe COVID-19 in Saudi, but its effect is not uniform. Risk is higher when diabetes is poorly controlled, advanced, or combined with obesity, hypertension, kidney disease, and older age. This makes diabetes severity and cardiometabolic clustering central to risk assessment in Saudi COVID-19 patients.

5. CLINICAL OUTCOMES AND COMPLICATIONS

The clinical course of COVID-19 is generally more severe in people with diabetes. This pattern was consistent across hospital cohorts, ICU populations and mortality analyses. Diabetes is associated with more inflammation, more organ dysfunction and poor clinical recovery. A review showed that diabetes was associated with higher mortality, more severe COVID-19, higher risk of acute respiratory distress syndrome and increased disease progression [8]. One of the main complications is acute respiratory distress syndrome. This is biologically plausible as diabetes is associated with impaired innate and adaptive immunity, and chronic low-grade inflammation, endothelial dysfunction and oxidative stress [8], [34]. These baseline abnormalities can predispose to increased lung injury if SARS-CoV-2 triggers a robust inflammatory response [35]. It can result in diffuse alveolar damage, hypoxaemia, respiratory failure, and increased requirement for oxygen escalation, non-invasive ventilation, mechanical ventilation, and ICU care [4]. Acute another important complication is kidney injury. In diabetes, the kidneys may already be at risk due to microvascular disease, chronic inflammation and pre-existing chronic kidney disease. COVID-19 can cause further injury through dehydration, systemic inflammation, endothelial injury, coagulopathy, haemodynamic instability, and possible direct tubular injury. Hospitalised COVID-19 patients often report severe outcomes of acute kidney injury, more often in

those with diabetes or chronic kidney disease [4]. This is of clinical importance, as acute kidney injury impacts fluid strategy, insulin requirements, medication dosing and prognosis. Cardiovascular complications are of frequent clinical importance. Endothelial dysfunction, dyslipidaemia, and cardiometabolic stress are often present in people with diabetes who present with COVID-19 [36]. This background risk may play a role in myocardial injury, arrhythmia, heart failure decompensation, thrombotic
events, and haemodynamic instability during acute infection. Cardiovascular disease and heart failure have been repeatedly identified as predictors of poor outcomes and mortality among patients with diabetes and COVID-19 [31]. Mechanistically, inflammation, coagulopathy, hypoxaemia, and pre-existing vascular injury may all converge in a single patient [34]. Acute metabolic emergencies have also been seen during the pandemic [36], [37]. Diabetic ketoacidosis and hyperosmolar hyperglycaemic state were seen in patients with known diabetes and, in some instances, as the initial presentation of previously undiagnosed or newly emergent dysglycemia [29], [38], [39]. These events may be due to stress hyperglycemia, insulin resistance, decreased intake, dehydration, delayed medical evaluation, steroid exposure and possible pancreatic beta-cell injury. There is emerging evidence that SARS-CoV-2 infection may also be associated with new-onset diabetes or worsening glycaemic control, but the causal pathways are still under investigation [11]. These acute metabolic complications have immediate clinical implications. Severe hyperglycemia, insulin deficiency, severe infection, dehydration or late access to care should be expected to have diabetic ketoacidosis and hyperosmolar hyperglycaemic state [39]. It is important to monitor pH, ketones, beta-hydroxybutyrate, renal function and electrolytes early. Insulin remains the main therapy in these acute metabolic states. The long-term effects are less well defined but are still clinically significant. Post-COVID conditions in people with diabetes may include fatigue, reduced physical capacity, psychological symptoms, worsening glucose control, and possible cardiovascular or renal sequelae. Post-discharge metabolic follow-up is supported by evidence from large cohort and meta-analytic studies that show an increased risk of incident diabetes after COVID-19 [11]. Therefore, diabetic patients should be evaluated for recovery not only by hospital discharge, but also by structured follow-up of metabolic, renal, cardiovascular and psychological outcomes. There are many recurrent predictors of mortality across studies. Older age, obesity, chronic kidney disease, cardiovascular disease, heart failure and hypertension are consistently associated with worse outcomes [31]. In addition, laboratory markers such as elevated CRP, abnormal liver enzymes, leukocyte changes, and lymphopenia have been associated with poor prognosis in COVID-19 [8]. Another important factor is glycaemic control. However, some studies showed that HbA1c is a good predictor and some studies showed that admission glucose and acute inflammatory markers are more predictive than long-term glycaemic history. This suggests that outcomes are affected by both chronic glucose exposure and acute metabolic instability, but through different mechanisms.

6. IMPACT OF COVID-19 ON DIABETES MANAGEMENT

The COVID-19 pandemic affected diabetes management in Saudi Arabia in addition to the risk of infection per itself. It was disruptive to the daily routines of patients and healthcare workers, disrupted their regular care, and added new stressors [17]. For many with diabetes, management became more difficult as the systems that support control-regular clinic visits, stable routines, physical activity, education and monitoring-were disrupted. Saudi Arabia: Lifestyle changes and psychological burden were linked to lockdown in adults with type 1 and type 2 diabetes [14], [40]. Saudi Gradual restrictions from March 2020 in Arabia were important for infection control but also impacted chronic disease management. A national survey of adults with diabetes in Saudi Arabia identified decreased physical activity, changes in diet, depression, psychological stress, and changes in the timing, content, and number of meals [14], [40]. Physical activity decreased especially in people with type 1 diabetes [14], [40], [41]. These findings are important because diabetes management is largely dictated by daily routines. Treatment is regular meals, movement, sleep and glucose monitoring-not additions to lifestyle. The Jeddah study demonstrated a similar pattern [40]. Only 49.6% of the participants reported regular blood glucose monitoring during lockdown and many reported changes in eating habits, sleep disturbance and fear of infection [42]. The lockdown did not simply restrict mobility in practice but disrupted the daily routines that enabled effective self-management. It also disrupted routine healthcare during the pandemic. Diabetes care often involves repeated outpatient visits, laboratory follow-up, medication review, and patient education. During the pandemic, there was specific guidance issued by national authorities for diabetes and telehealth services expanded rapidly in order to maintain continuity of care [29]. Digital tools and apps provided access to services, communication and triage, helping prevent a total collapse of chronic disease care. However, the resilience was short. Remote care-maintained contact with many patients but could not replace structured chronic disease management. Mean HbA1c in a large Saudi multicentre telemedicine study of 4,266 patients with type 2 diabetes increased marginally from 8.52% pre-lockdown to 8.68% post-lockdown [43], [44]. About 24.9% of patients improved at least 0.5%, and 36.9% worsened at least 0.5% [33], [43], [45]. While 63.1% improved or remained stable, overall glycaemic control remained suboptimal highlighting the fact that telemedicine helped prevent more severe care disruption but was not enough to ensure good control for all patients [41], [45]. Another layer is added by medication adherence. The pandemic disrupted access to drugs and continuity of

treatment in many settings globally. Evidence from Saudi Arabia suggests a more stable pharmaceutical environment. In Jeddah study, strict adherence to their prescribed medications was reported by 59.4% of participants and most did not have significant difficulty in obtaining medications or glucose monitoring supplies [40], [42]. However, adherence to medication alone was not enough to achieve overall control of diabetes. Many patients struggled with exercise, diet, self-monitoring and psychological stress, but were adherent. This may account for the mixed glycaemic outcomes rather than uniformly poor outcomes during the pandemic. International studies reported mixed effects of lockdown on glycaemic control with some populations worsening and others stable or improving with baseline control, family support, self-management and access to care [46]. The Saudi findings seem in line with this larger pattern. The pandemic did not affect all patients equally. Some patients deteriorated, some remained stable and a smaller group improved, perhaps due to remote care, family support or more structured home routines compensating for decreased access to clinics. Saudi Arabia showed moderate but meaningful resilience compared with international evidence. The country avoided serious medication shortages and total service collapse, adopted telemedicine at a relatively early stage, and supported continuity through national guidance and digital tools. The more challenging aspects of diabetes management, however, were behavioural stability, education, routine monitoring and ongoing glycaemic control. This moves the conversation beyond access alone, to quality and continuity of management of chronic disease.

7. DIGITAL HEALTH IN DIABETES CARE DURING COVID-19

The pandemic forced diabetes care in Saudi Arabia to be more digital. This shift was driven out of necessity in response to lockdowns, infection risk and limited face-to-face visits. Telemedicine went from a supplemental option to an essential tool. Saudi evidence suggests that remote consultations were used for both existing and newly diagnosed diabetes and almost 60,000 patients had benefited from these services in the Kingdom by August 2020 [29]. A key component was the roll-out of virtual clinics. Saudi health care teams rapidly set up telemedicine pathways for diabetes care during the outbreak, and local evidence suggests that this approach helped to keep treatment going when routine clinic visits were curtailed [47]. The large Saudi multicentre study on telemedicine during lockdown revealed widespread adoption of virtual clinics within Ministry of National Guard Health Affairs hospitals [43], [47]. Although glycaemic control did not improve uniformly, telemedicine likely prevented more severe disruption in follow-up. Digital care was thus useful but not a full replacement for structured in-person chronic disease management. Another part was remote monitoring, especially glucose monitoring. The reason why this mattered is explained in the broader diabetes-COVID literature. Continuous glucose monitoring decreased contact points between patients and healthcare providers, facilitated outpatient care and improved remote decision-making [8], [48]. It also allowed for closer monitoring of glucose in isolation settings and provided a reduction in the need for invasive bedside testing. Telemedicine and remote glucose monitoring were particularly pertinent for insulin users and those needing close surveillance [48]. Saudi Arabia also enjoyed national digital initiatives. Mobile applications such as Seha, Mawid, and Tawakkalna have helped in teleconsultation, access to appointments, tracking of COVID-19 and public health control during the pandemic [29]. The widespread expansion of digital health has been facilitated by the national e-health transformation agenda and Vision 2030. A Saudi systematic review showed that the Sehhaty platform has more than 24 million users, which means the government has invested a lot in the platform and the public widely adopted it. Access to eHealth, reduced exposure to infection and supported continuity of care. The Saudi systematic review found moderate certainty evidence for improvement of HbA1c and medication adherence with digital interventions especially mobile applications and SMS support. However, it's not without its challenges. Telemedicine cannot substitute for physical examination, and barriers such as internet quality, device cost, lower rural adoption, and variable digital literacy may limit its reach [49]. Long-term engagement also is grown up.

8. COVID-19 VACCINATION IN PATIENTS WITH DIABETES

Vaccination quickly became a key protective measure for people with diabetes during the pandemic. Diabetes has consistently been associated with more severe COVID-19, higher complication rates, and increased mortality [4], [50]. During the pandemic, review articles recommended prioritizing individuals with diabetes for vaccination regardless of diabetes type and integrating vaccination into routine risk management rather than treating it as optional [48]. An initial concern was whether people with diabetes would mount a weaker immune response to COVID-19 vaccines. Although evidence was limited in 2021, it was reassuring. A review reported largely similar humoral responses to several SARS-CoV-2 antigens in patients with and without diabetes [48]. These findings fit the concept that diabetes is not a major barrier to an effective vaccine-induced immune protection in most patients. Vaccine effectiveness in diabetes depends not only on antibody production but also on whether vaccination prevents severe disease in a high-risk population. The broader literature suggests that vaccination remains effective and clinically valuable for people with diabetes, although mechanistic evidence is less complete than outcome-based evidence [48]. The quality of evidence varies, as early studies were mainly observational rather than randomized diabetes-specific vaccine trials, limiting precision when comparing type 1 and type 2 diabetes or well-controlled and poorly controlled disease [5], [48]. Evidence on breakthrough infections in diabetes remains limited in the Saudi-specific literature. The

existing reviews focus more on severity reduction, prioritization and rollout than detailed breakthrough infection analysis [29], [48]. This remains an important gap because breakthrough risk depends on overlapping factors, including age, obesity, kidney disease, immune status, time since vaccination, and variant type. Diabetes may therefore operate within a broader cardiometabolic risk profile rather than acting alone. The Saudi vaccination strategy was early and structured. A review in Saudi Arabia said the Pfizer-BioNTech vaccine was approved in mid-December 2020, and the Oxford-AstraZeneca vaccine was approved in February 2021. Vaccines were provided free of charge to citizens and expats, with priority given to high-risk groups, including people with diabetes [29]. As of July 15, 2021, over 21.5 million doses had been administered in 587 sites across the Kingdom [29]. Safety concerns should be interpreted cautiously. A Saudi systematic review reported a small number of autoimmune diabetes cases after COVID-19 vaccination, often in genetically predisposed individuals, and concluded that the overall benefits of vaccination strongly outweigh the potential risks [51]. Case reports are useful for signal detection, but they provide weak evidence for causality. COVID-19 vaccination for patients with diabetes is therefore supported by a favourable risk-benefit balance. The strongest evidence indicates protection against severe outcomes, while data on diabetes-specific immune responses and breakthrough infections remain less complete. Saudi Arabia's vaccination strategy was swift, targeted, and consistent with the increased risks for people with diabetes.

9. HEALTHCARE SYSTEM IMPACT AND POLICY IMPLICATIONS

The pandemic challenged the control of infection in Saudi Arabia and exposed the strengths and weaknesses of its health system, especially in diabetes care. The COVID-19 pandemic demonstrated the resilience and adaptability of the system but also exposed the fragility of managing chronic diseases. In policy terms, the Saudi response demonstrated institutional capacity but also demonstrated that emergency preparedness is not the same as chronic disease readiness. Saudi responded swiftly with national guidance, digital tools and service reorganisation. Diabetes-specific guidance was issued by national bodies and telehealth platforms expanded rapidly to facilitate continuity of care [29]. Saudi Arabia tried to tackle both at the same time, unlike many systems that initially focused on infection control and then dealt with the disruption to chronic disease. Another strength was digital governance. Platforms and mobile applications were used to track infections, access care, remote consultations and follow-ups. These were further complemented with Vision 2030 reforms and the broader digital health agenda. The pandemic also highlighted critical gaps in chronic disease care. Access to medication remained stable, but the ability to maintain structured diabetes management was harder to maintain. Routine follow-up, laboratory tests, physical activity, dietary stability, and patient education all decreased during the pandemic [14]. A health system can dispense prescriptions, and still not keep control of diseases. Diabetes control is a function of continuity and not merely availability of medication. This is also reflected in the wider chronic care literature. Reviews of Saudi pharmacy and chronic disease management show a transition to patient-centered, team-based care, but structural barriers exist including workforce shortages, variable implementation, and limited operational structures for expanded multidisciplinary roles [52]. The COVID-19 experience demonstrates that these are not trivial administrative issues. Clinics are in chaos and the system is relying on chemists, telehealth teams, primary care networks, data systems and more to take the pressure. This is a direct tie to resource allocation. The challenge for Saudi Arabia is not simply to spend more, but to spend better. The country is facing a considerable burden of chronic diseases such as diabetes, obesity and hypertension which is placing pressure on hospitals and specialist clinics [52]. The pandemic experience suggests resources should support not only tertiary acute care but also primary care continuity, remote monitoring, medication management, digital literacy and chronic disease follow-up. Preparedness for future pandemics, therefore, must go beyond stockpiles and hospital beds. It should include population health intelligence, real time monitoring of chronic disease, and risk stratification. This is reflected in the Saudi Population Health Observatory. It was meant to improve disease burden tracking, consolidate national data sources, support policy implementation and allow AI-driven forecasting and targeted interventions [53], [54]. This is a transition from reactive healthcare to predictive and population planning. However, the Population Health Observatory review also highlights persistent challenges such as fragmented data, inconsistent data quality, gaps in digital infrastructure and unclear governance between institutions [53]. For data systems to be transformative, they must be interoperable, trusted and action-oriented. Otherwise, they tend to be descriptive, rather than operationally useful. Diabetes and other chronic diseases must be a core part of emergency planning for Saudi Arabia's future readiness, not an afterthought. Resilience in the face of future large-scale disruptions will require stronger primary care and multidisciplinary teams, as well as home-based monitoring and integrated data systems.

10. CONCLUSION

The evidence reviewed here indicates that diabetes mellitus was a common comorbidity during the COVID-19 pandemic in Saudi Arabia and a major determinant of vulnerability. Diabetes was associated with higher rates of hospitalisation, ICU admission, acute respiratory distress syndrome, acute kidney injury, cardiovascular events, metabolic crises (diabetic ketoacidosis and hyperosmolar hyperglycaemic state) and death [4]. These results were driven by diabetes itself, but also by poor glycaemic control, obesity, hypertension, kidney disease, and older age [31]. The pandemic also revealed weaknesses in diabetes management, such as

how lockdowns disrupted diet, reduced physical activity, increased psychological stress and challenged routine self-care [14]. Saudi Arabia showed strong resilience in its systems by quickly issuing guidance, ramping up telemedicine, using digital platforms and rolling out vaccination [29]. However, the experience has also revealed inadequacies in chronic disease continuity, risk assessment and integrated long-term care. This is particularly relevant as Saudi Arabia entered the pandemic with a high rate of diabetes and metabolic disorders. Diabetes preparedness should therefore be considered a national public health priority and not a narrow speciality concern. "Moving forward, we will need stronger primary care, better remote monitoring, interoperable health data and active population health approaches.

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