World Journal of Diabetes

Submit a Manuscript: https://www.f6publishing.com

World J Diabetes 2021 March 15; 12(3): 198-205

DOI: 10.4239/wjd.v12.i3.198

ISSN 1948-9358 (online)

OPINION REVIEW

Diabetes and COVID-19: Diseases of racial, social and glucose intolerance

Tahseen A Chowdhury

ORCID number: Tahseen A Chowdhury 0000-0001-8878-2331.

Author contributions: The author conceived of the manuscript and wrote the entire manuscript on his own.

Conflict-of-interest statement: The author declares no conflicts of interest.

Manuscript source: Invited manuscript

Specialty type: Endocrinology and metabolism

Country/Territory of origin: United Kingdom

Peer-review report's scientific quality classification

Tahseen A Chowdhury, Department of Diabetes and Metabolism, The Royal London Hospital, London E1 1BB, United Kingdom

Corresponding author: Tahseen A Chowdhury, FRCP, MD, Professor, Department of Diabetes and Metabolism, The Royal London Hospital, Whitechapel, London E1 1BB, United Kingdom. tahseen.chowdhury@nhs.net

Abstract

Diabetes and coronavirus disease 2019 (COVID-19) are worldwide pandemics that have had a major impact on public health throughout the globe. Risk factors for developing diabetes and having adverse outcomes of COVID-19 appear to be similar; metabolic factors (such as obesity), non-White ethnicity and poorer socioeconomic status appear to be risk factors for both. Diabetes and COVID-19 have a significant effect on populations adversely affected by health inequality. Whilst we hope that COVID-19 will be mitigated by widespread use of vaccines, no such prospect exists for mitigating the pandemic of diabetes. In this brief opinion review, I compare risk factors for diabetes and adverse outcomes of COVID-19 and argue that tackling health and social inequality is likely to play a major role in solving the global diabetes pandemic and improve outcomes of COVID-19.

Key Words: Diabetes; COVID-19; Ethnicity; Health inequality; Social inequality; Risk factors

Core Tip: Diabetes and coronavirus disease 2019 are both global pandemics that cause more severe disease in people of non-White ethnicity and lower socioeconomic status. Improving social justice and reducing health inequalities will reduce the risk of both conditions considerably.

Citation: Chowdhury TA. Diabetes and COVID-19: Diseases of racial, social and glucose intolerance. *World J Diabetes* 2021; 12(3): 198-205

URL: https://www.wjgnet.com/1948-9358/full/v12/i3/198.htm

DOI: https://dx.doi.org/10.4239/wjd.v12.i3.198

Grade A (Excellent): A
Grade B (Very good): 0
Grade C (Good): C, C
Grade D (Fair): D, D
Grade E (Poor): 0

Received: November 25, 2020
Peer-review started: November 26, 2020
First decision: December 20, 2020
Revised: January 7, 2021
Accepted: January 22, 2021
Article in press: January 22, 2021
Published online: March 15, 2021

P-Reviewer: Aguado A, Infante M, Navarro-González JF, Sun X
S-Editor: Gao CC
L-Editor: Filipodia
P-Editor: Ma YJ

INTRODUCTION

Diabetes and coronavirus disease 2019 (COVID-19) are two global pandemics that have sharply contrasting features but also some significant similarities. COVID-19, caused by the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), emerged in 2019 and rapidly became a global public health emergency, leading to implementation of extraordinary public health measures and huge economic and societal costs[1]. At the time of writing, the condition has caused over 2000000 deaths worldwide[2]. However, this is likely to be less than 50% of the deaths due to diabetes in 2020; the condition caused 4200000 deaths worldwide in 2019[3], illustrating the fact that the diabetes pandemic has been perhaps more slow burning but no less fatal. The global diabetes prevalence in 2019 was estimated to be 9.3% (463000000 people), rising to 10.2% (578000000) by 2030 and 10.9% (700000000) by 2045[4].

In this viewpoint, I compare and contrast the two pandemics and their intersection, with particular reference to data from the United Kingdom.

DIABETES AND COVID-19 ARE RACIALLY INTOLERANT

Diabetes and ethnicity

For many years it has been recognised that type 2 diabetes mellitus (T2D) affects certain ethnic groups more than others. In the United Kingdom, this was first described in the Southall study, focusing on ethnicity in West London[5]. Older studies suggested a five-fold increased risk for the development of T2D amongst South Asians compared to White Europeans, although more recent data suggests that this risk is more in the region of 2-2.5 times greater[6]. There is also data to suggest that South Asians develop diabetes around 5 years earlier than their White European counterparts[7-9], and as duration of diabetes is a significant risk factor for development of complications, this means that South Asians are more likely to be susceptible to complications of diabetes at an earlier age. Indeed, complications such as cardiovascular disease, renal disease and eye disease are up to 50% higher than that of White Europeans[9-13]. Amongst other ethnicities in the United Kingdom, Black African and Caribbean ethnicities also show an increased risk for the development of T2D of around 1.5-2 times that of White Europeans[14].

The reason for the increased risk of T2D amongst South Asians is far from clear. Bhopal[14] proposed a four stage model suggesting that South Asian babies are genetically programmed to be small but with a high fat mass and low muscle mass with fewer pancreatic β-cells. In childhood and early adulthood, excess energy intake and lower physical activity leads to intra-abdominal fat accumulation, exacerbating insulin resistance with high insulin, glucose and triglycerides, a fatty liver and subsequent diabetes as β-cell failure ensues. Suggested factors contributing to this predisposition include genetic and epigenetic factors, low birthweight with rapid "catch-up" growth, ectopic fat within the liver and pancreas, low levels of adiponectin and high levels of leptin[15].

Whilst inherited effects may predispose to disease, cultural and lifestyle factors are likely to have a major impact on development of the condition. Dietary surveys suggest that a high proportion of daily energy intake originates from saturated fats and carbohydrates amongst South Asians[6]. Smoking is also common amongst South Asian men, in particular of Bangladeshi and Pakistani origin. South Asian subjects also appear to have a more sedentary lifestyle compared to Europeans[16]. Diabetes is commoner amongst more socially deprived cohorts in the United Kingdom, and non-White ethnicities are over-represented amongst socially deprived groups in the United Kingdom[17].

COVID-19 and ethnicity

At the height of the COVID-19 pandemic, it became increasingly clear that certain ethnic groups were more severely affected by SARS-CoV-2 infection[18]. In the United Kingdom, data from over 6000000 adults from 1205 general practices suggested that compared to White Europeans, the hazard ratio (HR) for death in men from COVID-19 (adjusted for age, body mass index and deprivation) amongst British Indians was 1.59 [95% confidence interval (CI) 1.25-2.01], British Pakistanis 1.84 (1.39-2.44), British Bangladeshis 2.27 (1.65-3.12), British Caribbeans 2.06 (1.65-2.57) and British Black Africans 3.03 (2.42-3.80)[19]. Similar data was seen for admission to hospital with severe COVID-19.

The cause of this excess risk of death and adverse outcome from COVID-19 amongst

non-White ethnicities is unclear but likely to be multifactorial. Underlying genetic factors may be important but as yet not ascertained, but it is notable that disparate ethnic groups are more severely affected, so a common genetic factor seems less likely. Increased risk of metabolic conditions such as diabetes, obesity and hypertension are also seen in these groups, perhaps suggesting an underlying predisposition to metabolic conditions and COVID-19[6,14].

Furthermore, socioeconomic factors and overcrowded housing are also cited as possible contributing factors. In particular, multigenerational households, with the old and young living in close proximity, is likely to increase risk of exposure of the elderly to SARS-CoV-2 and make it more difficult for infected patients to self-isolate. In addition, non-White ethnic groups work in more exposure prone settings, such as cleaners, health care workers, carers and taxi drivers.

DIABETES AND COVID-19 ARE SOCIALLY INTOLERANT

Diabetes and socioeconomic deprivation

There is considerable data to suggest that the prevalence of T2D is increased in areas of lower socioeconomic status. The British 1958 birth cohort study measured glycated haemoglobin at age 45 years and showed a higher prevalence of values of 5.5% (37 mmol/mol) and above in people with occupational social class 3, 4 and 5 compared to higher social class groups[20]. The Whitehall II study undertook doctor diagnosis and oral glucose tolerance tests to identify T2D, and amongst men the incidence of T2D in the lowest employment grade was more than two times that of the highest employment grade, even when adjusted for obesity and sedentary lifestyle[21]. More recent data confirms that prevalence of T2D is strongly associated with socioeconomic deprivation, most pronounced in the 40-69 year age band[17]. Interestingly, a cross-sectional school-based study of 4804 United Kingdom children aged 9-10 years, suggested that socioeconomic status of the child impacted metabolic indices according to ethnicity; White European children of lower socioeconomic status had poorer metabolic indices, whereas amongst South Asian children, socioeconomic status did not appear to affect metabolic indices[22].

Socioeconomic deprivation may also impact treatment of diabetes. In the United Kingdom, it has been shown that more deprived areas have lower attainment for diabetes care processes or diabetes targets compared to less deprived areas[23].

COVID-19 and socioeconomic deprivation

The data on over 6000000 patients from 1205 United Kingdom general practices referred to above also showed a significant impact of deprivation on the development of COVID-19 adverse outcomes[19]. A five unit increase in the Townsend material deprivation score led to a HR for death of 1.50 (95%CI 1.40-1.61) and similar increased risk of hospital admission for men and women from COVID-19. Data from the Office of National Statistics confirm this. The death rate of the population in the most deprived areas was 128.3 deaths per 100000, which was more than double that of the least deprived areas where the death rate was 58.8 deaths per 100000[24].

COVID-19 (LIKE DIABETES) IS GLUCOSE INTOLERANT

As the COVID-19 pandemic progressed, emerging data showed that people with diabetes and hypertension were uniquely at risk for increased severity of SARS-CoV-2 infection[25]. Amongst intensive care patients with COVID-19 in China, 22% of 32 patients who died had diabetes[26], and risk of admission to intensive care was doubled in patients with diabetes[27]. Subsequent studies suggested between 12%-16% of patients with severe disease had diabetes[28,29], and mortality was up to three-fold higher[30,31]. This mirrors previous data on outbreaks of other coronavirus infections (SARS and Middle East Respiratory Syndrome) and severe influenza from H1N1 pandemics, which also showed that diabetes was an important risk marker for adverse outcomes[32-34].

In the United Kingdom, the largest dataset to have reported on this topic examined over 61000000 individuals on general practice registers. Of these, 263830 (0.4%) had type 1 diabetes (T1D), and 2864670 (4.7%) had T2D[35]. One third of all deaths from COVID-19 occurred in people with diabetes (31.4% in people with T2D and 1.5% in people with T1D). The HRs for in-hospital death from COVID-19 (adjusted for age,

sex, deprivation, ethnicity, geographical region) compared to people without diabetes were 3.51 (95%CI 3.16-3.90) in people with T1D and 2.03 (95%CI 1.97-2.09) in people with T2D. When adjusted for previous hospital admission with cardiovascular disease or heart failure, the HRs reduced to 2.86 (95%CI 2.58-3.18) for T1D and 1.80 (95%CI 1.75-1.86) for T2D.

A large United Kingdom study of a cohort of patients with diabetes and COVID-19 found that poor glycaemic control prior to hospital admission was associated with an increased risk of in-hospital death[36]. Compared with people with a haemoglobin A1c (HbA1c) of 48-53 mmol/mol (6.5%-7.0%), people with an HbA1c of 86 mmol/mol (10.0%) or higher had increased COVID-19-related mortality (HR 2.23, 95%CI 1.50-3.30, $P < 0.0001$ in T1D and HR 1.61, 1.47-1.77, $P < 0.0001$ in T2D). In people with T2D compared to those with HbA1c of 48-53 mmol/mol, mortality from COVID-19 was significantly higher in those with an HbA1c > 59 mmol/mol (7.5%) (HR 1.22, 95%CI 1.15-1.30, $P < 0.0001$). In a United States study of 451 patients with diabetes and/or uncontrolled hyperglycaemia, mortality rate was 28.8% in patients with uncontrolled hyperglycaemia compared with 6.2% in patients without hyperglycaemia ($P < 0.001$)[37]. In a retrospective analysis of 952 cases of COVID-19 in patients with T2D in China, well-controlled blood glucose in hospital (capillary blood glucoses 3.9 to 10.0 mmol/L) was associated with lower mortality compared to individuals with poorly controlled glycaemia (capillary blood glucoses frequently > 10.0 mmol/L) (HR 0.14, 95%CI 0.03-0.60)[38].

Why should diabetes increase the risk of adverse outcomes in patients with COVID-19? The presence of diabetes does appear to impair immune responsiveness, and poor glucose control appears to impair several aspects of the immune response to viral infection whilst also increasing the risk of secondary bacterial infection[39]. There appears to be a J-shaped curve between HbA1c and risk of hospital admission with infection[40]. Diabetes per se does not appear to increase the risk of infection with SARS-CoV-2, only its severity.

Many patients with T2D have central obesity, which also appears to be an independent risk factor for adverse outcomes, independent of diabetes status[41]. This may be due to the accompanying low grade inflammation and release of adipocytokines such as tumour-necrosis factor-alpha or transforming growth factor-beta from adipocytes, which may impair immune response[42]. Obstructive sleep apnoea or heart failure, common co-morbidities associated with obesity, may impair respiratory capacity thereby inhibiting adequate ventilation and exacerbating respiratory compromise[43].

People with diabetes frequently have co-morbid complications such as chronic kidney disease or cardiovascular disease. Acute kidney injury is known to be an adverse risk factor in COVID-19 infection[44], and people with diabetes have an increased risk of acute kidney injury[45].

Further interest has focused on the angiotensin-converting enzyme-2 receptor, which is known to facilitate SARS-CoV-2 spike protein binding and cellular infection[46]. Human pancreatic tissue widely expresses angiotensin-converting enzyme-2, and it has been suggested that viral infection may cause acute β-cell dysfunction, leading to hyperglycaemia[47,48]. Indeed, there is growing evidence that acute hyperglycaemia occurs in COVID-19 infection, and a number of reports from the United Kingdom suggest that hyperglycaemic emergencies are a common presenting finding in COVID-19 infection[49,50].

The common risk factors for diabetes and severe COVID-19 infection are shown in Table 1.

WHY DO PEOPLE WITH DIABETES, NON-WHITE ETHNICITY AND LOWER SOCIOECONOMIC GROUP GET POORER OUTCOMES WITH COVID-19?

The preceding discussion suggests that adverse outcomes associated with COVID-19 and T2D have similar risk factors; non-White ethnicity, poorer socioeconomic status and metabolic factors such as obesity and metabolic syndrome. Why should this be?

The common factor in all of these risk factors is health inequality. The World Health Organization states that factors contributing to health inequality include where we are born, how we live and how we work[49]. Public Health England described an "un-level playing field" whereby a social gradient means that people who have a good start in life, feel in control of their life, have good and fair employment, a healthy standard of living and a safe home and good community have much better health outcomes compared to those who do not have these[50]. In 2010 in the United Kingdom, the

Table 1 Common risk factors for diabetes and adverse outcomes of coronavirus disease 2019

Common risk factors
Hypertension
Obesity
Glucose intolerance
Non-White ethnicity
Lower socioeconomic status
Cancer
Chronic kidney disease

Marmot review on social inequality suggested that "inequalities that are preventable by reasonable means are unfair. Putting them right is a matter of social justice"[51].

Concerted action to reduce health and social inequalities is likely to reduce the huge health inequalities seen in both the diabetes and COVID-19 pandemics. Some potential solutions are outlined in Table 2.

CONCLUSION

The COVID-19 pandemic will hopefully be tackled by widespread vaccination over the coming year. However, it is unlikely that the pandemic of T2D will be tackled in 2021. A major way to deal with the diabetes pandemic is to tackle health and social inequalities that lead to great disparities in health between ethnic and socioeconomic groups. It is my earnest hope that once the COVID-19 pandemic is over, the world will turn to tackling the much more difficult issue of health and social inequality that blights the lives of millions throughout the world.

Table 2 Potential interventions to reduce health inequality and rate of diabetes increase

Potential interventions
National programmes to improve the nation's health focus on improved diet and physical activity
Green solutions to transport/energy
"Fat/Sugar tax" and use funds to subsidise healthy food
Reduce licensing of unhealthy eating places in poorer areas
Minimum alcohol unit pricing
Tackle advertising of calorie dense foods to children and prevent sponsorship of sports by unhealthy food companies
Education for children to increase physical activity in and improve knowledge of healthy living in schools
Improve culturally appropriate interventions to educate people living with long term conditions

REFERENCES

1 **Munster VJ**, Koopmans M, van Doremalen N, van Riel D, de Wit E. A Novel Coronavirus Emerging in China - Key Questions for Impact Assessment. *N Engl J Med* 2020; **382**: 692-694 [PMID: 31978293 DOI: 10.1056/NEJMp2000929]

2 **Worldometer**. COVID-19 coronavirus pandemic. [cited October 21, 2020]. Available from: https://www.worldometers.info/coronavirus/

3 **International Diabetes Federation**. [cited October 21, 2020]. Available from: https://www.idf.org/e-library/epidemiology-research/diabetes-atlas/134-idf-diabetes-atlas-8th-edition.html

4 **Mather HM**, Keen H. The Southall Diabetes Survey: prevalence of known diabetes in Asians and Europeans. *Br Med J (Clin Res Ed)* 1985; **291**: 1081-1084 [PMID: 3931804 DOI: 10.1136/bmj.291.6502.1081]

5 **Holman N**, Forouhi NG, Goyder E, Wild SH. The Association of Public Health Observatories (APHO) Diabetes Prevalence Model: estimates of total diabetes prevalence for England, 2010-2030. *Diabet Med* 2011; **28**: 575-582 [PMID: 21480968 DOI: 10.1111/j.1464-5491.2010.03216.x]

6 **UK Prospective Diabetes Study**. XII: Differences between Asian, Afro-Caribbean and white Caucasian type 2 diabetic patients at diagnosis of diabetes. UK Prospective Diabetes Study Group. *Diabet Med* 1994; **11**: 670-677 [PMID: 7955993]

7 **Tillin T**, Hughes AD, Godsland IF, Whincup P, Forouhi NG, Welsh P, Sattar N, McKeigue PM, Chaturvedi N. Insulin resistance and truncal obesity as important determinants of the greater incidence of diabetes in Indian Asians and African Caribbeans compared with Europeans: the Southall And Brent REvisited (SABRE) cohort. *Diabetes Care* 2013; **36**: 383-393 [PMID: 22966089 DOI: 10.2337/dc12-0544]

8 **Gholap N**, Davies M, Patel K, Sattar N, Khunti K. Type 2 diabetes and cardiovascular disease in South Asians. *Prim Care Diabetes* 2011; **5**: 45-56 [PMID: 20869934 DOI: 10.1016/j.pcd.2010.08.002]

9 **Bhopal R**, Unwin N, White M, Yallop J, Walker L, Alberti KG, Harland J, Patel S, Ahmad N, Turner C, Watson B, Kaur D, Kulkarni A, Laker M, Tavridou A. Heterogeneity of coronary heart disease risk factors in Indian, Pakistani, Bangladeshi, and European origin populations: cross sectional study. *BMJ* 1999; **319**: 215-220 [PMID: 10417082 DOI: 10.1136/bmj.319.7204.215]

10 **Anand SS**, Yusuf S, Vuksan V, Devanesen S, Teo KK, Montague PA, Kelemen L, Yi C, Lonn E, Gerstein H, Hegele RA, McQueen M. Differences in risk factors, atherosclerosis, and cardiovascular disease between ethnic groups in Canada: the Study of Health Assessment and Risk in Ethnic groups (SHARE) Lancet 2000; 356: 279-284 [PMID: 11071182 DOI: 10.1016/s0140-6736(00)02502-2]

11 **Balarajan R**. Ethnic differences in mortality from ischaemic heart disease and cerebrovascular disease in England and Wales. *BMJ* 1991; **302**: 560-564 [PMID: 2021718 DOI: 10.1136/bmj.302.6776.560]

12 **Dreyer G**, Hull S, Aitken Z, Chesser A, Yaqoob MM. The effect of ethnicity on the prevalence of diabetes and associated chronic kidney disease. *QJM* 2009; **102**: 261-269 [PMID: 19147658 DOI: 10.1093/qjmed/hcn177]

13 **Chaturvedi N**, McKeigue PM, Marmot MG. Relationship of glucose intolerance to coronary risk in Afro-Caribbeans compared with Europeans. *Diabetologia* 1994; **37**: 765-772 [PMID: 7988778 DOI: 10.1007/BF00404333]

14 **Bhopal RS**. A four-stage model explaining the higher risk of Type 2 diabetes mellitus in South Asians compared with European populations. *Diabet Med* 2013; **30**: 35-42 [PMID: 22998210 DOI: 10.1111/dme.12016]

15 **Peterson DB**, Dattani JT, Baylis JM, Jepson EM. Dietary practices of Asian diabetics. *Br Med J (Clin Res Ed)* 1986; **292**: 170-171 [PMID: 3080119]

16 **Khunti K**, Singh AK, Pareek M, Hanif W. Is ethnicity linked to incidence or outcomes of covid-19? *BMJ* 2020; **369**: m1548 [PMID: 32312785 DOI: 10.1136/bmj.m1548]

17 **Clift AK**, Coupland CAC, Keogh RH, Diaz-Ordaz K, Williamson E, Harrison EM, Hayward A, Hemingway H, Horby P, Mehta N, Benger J, Khunti K, Spiegelhalter D, Sheikh A, Valabhji J, Lyons RA, Robson J, Semple MG, Kee F, Johnson P, Jebb S, Williams T, Hippisley-Cox J. Living risk prediction algorithm (QCOVID) for risk of hospital admission and mortality from coronavirus 19 in adults: national derivation and validation cohort study. *BMJ* 2020; **371**: m3731 [PMID: 33082154 DOI: 10.1136/bmj.m3731]

18 **Thomas C**, Hyppönen E, Power C. Diabetes risk in British adults in mid life: a national prevalence study of glycated haemoglobin. *Diabet Med* 2007; **24**: 317-321 [PMID: 17305791 DOI: 10.1111/j.1464-5491.2006.02055.x]

19 **Kumari M**, Head J, Marmot M. Prospective study of social and other risk factors for incidence of type 2 diabetes in the Whitehall II study. *Arch Intern Med* 2004; **164**: 1873-1880 [PMID: 15451762 DOI: 10.1001/archinte.164.17.1873]

20 **Connolly V**, Unwin N, Sherriff P, Bilous R, Kelly W. Diabetes prevalence and socioeconomic status: a population based study showing increased prevalence of type 2 diabetes mellitus in deprived areas. *J Epidemiol Community Health* 2000; **54**: 173-177 [PMID: 10746110 DOI: 10.1136/jech.54.3.173]

21 **Thomas C**, Nightingale CM, Donin AS, Rudnicka AR, Owen CG, Sattar N, Cook DG, Whincup PH. Socio-economic position and type 2 diabetes risk factors: patterns in UK children of South Asian, black African-Caribbean and white European origin. *PLoS One* 2012; **7**: e32619 [PMID: 22412897 DOI: 10.1371/journal.pone.0032619]

22 **Barnard-Kelly KD**, Cherñavvsky D. Social Inequality and Diabetes: A Commentary. *Diabetes Ther* 2020; **11**: 803-811 [PMID: 32124269 DOI: 10.1007/s13300-020-00791-4]

23 **Office for National Statistics**. Deaths involving covid-19 by local area and socioeconomic deprivation: deaths occurring between 1 March and 31 May 2020. 12 June 2020. [cited October 21, 2020]. Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/deathsinvolvingcovid19bylocalareasanddeprivation/deathsoccurringbetween1marchand31may2020

24 **Hu Y**, Sun J, Dai Z, Deng H, Li X, Huang Q, Wu Y, Sun L, Xu Y. Prevalence and severity of corona virus disease 2019 (COVID-19): A systematic review and meta-analysis. *J Clin Virol* 2020; **127**: 104371 [PMID: 32315817 DOI: 10.1016/j.jcv.2020.104371]

25 **Yang X**, Yu Y, Xu J, Shu H, Xia J, Liu H, Wu Y, Zhang L, Yu Z, Fang M, Yu T, Wang Y, Pan S, Zou X, Yuan S, Shang Y. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. *Lancet Respir Med* 2020; **8**: 475-481 [PMID: 32105632 DOI: 10.1016/S2213-2600(20)30079-5]

26 **Li B**, Yang J, Zhao F, Zhi L, Wang X, Liu L, Bi Z, Zhao Y. Prevalence and impact of cardiovascular metabolic diseases on COVID-19 in China. *Clin Res Cardiol* 2020; **109**: 531-538 [PMID: 32161990 DOI: 10.1007/s00392-020-01626-9]

27 **Guan WJ**, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX, Liu L, Shan H, Lei CL, Hui DSC, Du B, Li LJ, Zeng G, Yuen KY, Chen RC, Tang CL, Wang T, Chen PY, Xiang J, Li SY, Wang JL, Liang ZJ, Peng YX, Wei L, Liu Y, Hu YH, Peng P, Wang JM, Liu JY, Chen Z, Li G, Zheng ZJ, Qiu SQ, Luo J, Ye CJ, Zhu SY, Zhong NS; China Medical Treatment Expert Group for Covid-19. Clinical Characteristics of Coronavirus Disease 2019 in China. *N Engl J Med* 2020; **382**: 1708-1720 [PMID: 32109013 DOI: 10.1056/NEJMoa2002032]

28 **Zhang JJ**, Dong X, Cao YY, Yuan YD, Yang YB, Yan YQ, Akdis CA, Gao YD. Clinical characteristics of 140 patients infected with SARS-CoV-2 in Wuhan, China. *Allergy* 2020; **75**: 1730-1741 [PMID: 32077115 DOI: 10.1111/all.14238]

29 **Yang J**, Zheng Y, Gou X, Pu K, Chen Z, Guo Q, Ji R, Wang H, Wang Y, Zhou Y. Prevalence of comorbidities and its effects in patients infected with SARS-CoV-2: a systematic review and meta-analysis. *Int J Infect Dis* 2020; **94**: 91-95 [PMID: 32173574 DOI: 10.1016/j.ijid.2020.03.017]

30 **Zheng Z**, Peng F, Xu B, Zhao J, Liu H, Peng J, Li Q, Jiang C, Zhou Y, Liu S, Ye C, Zhang P, Xing Y, Guo H, Tang W. Risk factors of critical & mortal COVID-19 cases: A systematic literature review and meta-analysis. *J Infect* 2020; **81**: e16-e25 [PMID: 32335169 DOI: 10.1016/j.jinf.2020.04.021]

31 **Yang JK**, Feng Y, Yuan MY, Yuan SY, Fu HJ, Wu BY, Sun GZ, Yang GR, Zhang XL, Wang L, Xu X, Xu XP, Chan JC. Plasma glucose levels and diabetes are independent predictors for mortality and morbidity in patients with SARS. *Diabet Med* 2006; **23**: 623-628 [PMID: 16759303 DOI: 10.1111/j.1464-5491.2006.01861.x]

32 **Wang W**, Chen H, Li Q, Qiu B, Wang J, Sun X, Xiang Y, Zhang J. Fasting plasma glucose is an independent predictor for severity of H1N1 pneumonia. *BMC Infect Dis* 2011; **11**: 104 [PMID: 21510870 DOI: 10.1186/1471-2334-11-104]

33 **Memish ZA**, Perlman S, Van Kerkhove MD, Zumla A. Middle East respiratory syndrome. *Lancet* 2020; **395**: 1063-1077 [PMID: 32145185 DOI: 10.1016/S0140-6736(19)33221-0]

34 **Barron E**, Bakhai C, Kar P, Weaver A, Bradley D, Ismail H, Knighton P, Holman N, Khunti K, Sattar N, Wareham NJ, Young B, Valabhji J. Associations of type 1 and type 2 diabetes with COVID-19-related mortality in England: a whole-population study. *Lancet Diabetes Endocrinol* 2020; **8**: 813-822 [PMID: 32798472 DOI: 10.1016/S2213-8587(20)30272-2]

35 **Holman N**, Knighton P, Kar P, O'Keefe J, Curley M, Weaver A, Barron E, Bakhai C, Khunti K, Wareham NJ, Sattar N, Young B, Valabhji J. Risk factors for COVID-19-related mortality in people with type 1 and type 2 diabetes in England: a population-based cohort study. *Lancet Diabetes Endocrinol* 2020; **8**: 823-833 [PMID: 32798471 DOI: 10.1016/S2213-8587(20)30271-0]

36 **Bode B**, Garrett V, Messler J, McFarland R, Crowe J, Booth R, Klonoff DC. Glycemic

Characteristics and Clinical Outcomes of COVID-19 Patients Hospitalized in the United States. *J Diabetes Sci Technol* 2020; **14**: 813-821 [PMID: 32389027 DOI: 10.1177/1932296820924469]

37 **Zhu L**, She ZG, Cheng X, Qin JJ, Zhang XJ, Cai J, Lei F, Wang H, Xie J, Wang W, Li H, Zhang P, Song X, Chen X, Xiang M, Zhang C, Bai L, Xiang D, Chen MM, Liu Y, Yan Y, Liu M, Mao W, Zou J, Liu L, Chen G, Luo P, Xiao B, Zhang C, Zhang Z, Lu Z, Wang J, Lu H, Xia X, Wang D, Liao X, Peng G, Ye P, Yang J, Yuan Y, Huang X, Guo J, Zhang BH, Li H. Association of Blood Glucose Control and Outcomes in Patients with COVID-19 and Pre-existing Type 2 Diabetes. *Cell Metab* 2020; **31**: 1068-1077. e3 [PMID: 32369736 DOI: 10.1016/j.cmet.2020.04.021]

38 **Geerlings SE**, Hoepelman AI. Immune dysfunction in patients with diabetes mellitus (DM). *FEMS Immunol Med Microbiol* 1999; **26**: 259-265 [PMID: 10575137 DOI: 10.1111/j.1574-695X.1999.tb01397.x]

39 **Critchley JA**, Carey IM, Harris T, DeWilde S, Hosking FJ, Cook DG. Glycemic Control and Risk of Infections Among People With Type 1 or Type 2 Diabetes in a Large Primary Care Cohort Study. *Diabetes Care* 2018; **41**: 2127-2135 [PMID: 30104296 DOI: 10.2337/dc18-0287]

40 **Kalligeros M**, Shehadeh F, Mylona EK, Benitez G, Beckwith CG, Chan PA, Mylonakis E. Association of Obesity with Disease Severity Among Patients with Coronavirus Disease 2019. *Obesity (Silver Spring)* 2020; **28**: 1200-1204 [PMID: 32352637 DOI: 10.1002/oby.22859]

41 **Almond MH**, Edwards MR, Barclay WS, Johnston SL. Obesity and susceptibility to severe outcomes following respiratory viral infection. *Thorax* 2013; **68**: 684-686 [PMID: 23436045 DOI: 10.1136/thoraxjnl-2012-203009]

42 **Dixon AE**, Peters U. The effect of obesity on lung function. *Expert Rev Respir Med* 2018; **12**: 755-767 [PMID: 30056777 DOI: 10.1080/17476348.2018.1506331]

43 **Pei G**, Zhang Z, Peng J, Liu L, Zhang C, Yu C, Ma Z, Huang Y, Liu W, Yao Y, Zeng R, Xu G. Renal Involvement and Early Prognosis in Patients with COVID-19 Pneumonia. *J Am Soc Nephrol* 2020; **31**: 1157-1165 [PMID: 32345702 DOI: 10.1681/ASN.2020030276]

44 **Hodgson LE**, Sarnowski A, Roderick PJ, Dimitrov BD, Venn RM, Forni LG. Systematic review of prognostic prediction models for acute kidney injury (AKI) in general hospital populations. *BMJ Open* 2017; **7**: e016591 [PMID: 28963291 DOI: 10.1136/bmjopen-2017-016591]

45 **Hoffmann M**, Kleine-Weber H, Schroeder S, Krüger N, Herrler T, Erichsen S, Schiergens TS, Herrler G, Wu NH, Nitsche A, Müller MA, Drosten C, Pöhlmann S. SARS-CoV-2 Cell Entry Depends on ACE2 and TMPRSS2 and Is Blocked by a Clinically Proven Protease Inhibitor. *Cell* 2020; **181**: 271-280. e8 [PMID: 32142651 DOI: 10.1016/j.cell.2020.02.052]

46 **Yang JK**, Lin SS, Ji XJ, Guo LM. Binding of SARS coronavirus to its receptor damages islets and causes acute diabetes. *Acta Diabetol* 2010; **47**: 193-199 [PMID: 19333547 DOI: 10.1007/s00592-009-0109-4]

47 **Huda MSB**, Shaho S, Trivedi B, Fraterrigo G, Chandrarajan L, Zolfaghari P, Dovey TM, Garrett CG, Chowdhury TA. Diabetic emergencies during the COVID-19 pandemic: A case-control study. *Diabet Med* 2021; **38**: e14416 [PMID: 33025636 DOI: 10.1111/dme.14416]

48 **Armeni E**, Aziz U, Qamar S, Nasir S, Nethaji C, Negus R, Murch N, Beynon HC, Bouloux P, Rosenthal M, Khan S, Yousseif A, Menon R, Karra E. Protracted ketonaemia in hyperglycaemic emergencies in COVID-19: a retrospective case series. *Lancet Diabetes Endocrinol* 2020; **8**: 660-663 [PMID: 32621809 DOI: 10.1016/S2213-8587(20)30221-7]

49 **World Health Organization**. Health inequality and their causes. [cited November 25, 2020]. Available from: https://www.who.int/news-room/facts-in-pictures/detail/health-inequities-and-their-causes

50 **Public Health England**. Health Inequality Resources. [cited November 25, 2020]. Available from: https://www.england.nhs.uk/about/equality/equality-hub/resources/

51 **Allen J MM**, Goldblatt P, Boyce T, McNeish D, Grady M. Geddes I. Fair Society, healthy lives: The Marmot Review. 2010. [cited November 25, 2020]. Available from: http://www.instituteofhealthequity.org/resources-reports/fair-society-healthy-lives-the-marmot-review/fair-society-healthy-lives-full-report-pdf.pdf

Published by **Baishideng Publishing Group Inc**
7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, USA
Telephone: +1-925-3991568
E-mail: bpgoffice@wjgnet.com
Help Desk: https://www.f6publishing.com/helpdesk
https://www.wjgnet.com