



# Improved glycemic control amongst people with long-standing diabetes during COVID-19 lockdown: a prospective, observational, nested cohort study

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Received: 10 September 2020 / Accepted: 6 October 2020 / Published online: 21 October 2020  
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## Abstract

**Background and aims** COVID-19 is likely to affect the lives of individuals with type 2 diabetes. However, the effect of COVID-19 lockdown on physical activity and glycemic control in such individuals is not known. We studied the physical activity and glycemic control during lockdown in comparison to pre-lockdown parameters in individuals with long-standing type 2 diabetes.

**Methods** This prospective, observational study includes 2240 people with T2DM regularly attending diabetes clinic prior to lockdown. Glycemic record, HbA1c, and physical activity assessed with Global Physical Activity Questionnaire (GPAQ) as metabolic equivalents (MetS min/week) were obtained during lockdown (minimum duration of 3 months).

**Results** A total of 422 out of 750 participants (nest) responded. The median (IQR) for age was 58 (52 to 64) years, duration of diabetes 11 (6 to 16) years, prevalent foot complications in 59.7%, and atherosclerotic cardiovascular disease in 21.3% of participants. There was a decrease in HbA1c from 7.8% (6.9 to 9.4) prior lockdown to 7.4% (6.6 to 8.7) during lockdown [ $\Delta$ HbA1c  $-0.41 \pm 0.27\%$  ( $p = 0.005$ )] and postprandial blood glucose 200.0 mg/dl (152.0 to 252.0) to 158.0 (140.0 to 200.0) mg/dl ( $p < 0.001$ ). The physical activity increased during lockdown from a GPAQ score 140 (0.0 to 1260) MetS to 840 (0.0 to 1680) MetS ( $p = 0.014$ ). The improvement of glycemic control was observed in either gender and independent of the presence of foot complications or increase in physical activity.

**Conclusions** There is an overall improvement of glycemic control during COVID-19 lockdown independent of increase in physical activity in people with long duration of diabetes.

**Keywords** COVID-19 · Glycemic control · HbA1c · Global Physical Activity Questionnaire (GPAQ) · Physical activity

## Introduction

COVID-19 due to SARS-CoV-2 infection was declared as global pandemic by WHO on 11 March 2020. It was suggested that the transmission may be significantly curbed by limitation of outdoor activities through the imposition of strict lockdown [1]. Subsequently, complete lockdown was enforced in India on March 25, 2020, until May 4, and partial lockdown is in place limiting daily activities at the time of writing the manuscript. A significant restriction of

outdoor physical activity during lockdown may have perpetuating influence on lifestyle disorders including obesity, hypertension, and diabetes. Sedentary lifestyles, poor dietary habits, and sleep deprivation are known potentially modifiable risk factors for poor glycemic control in people with diabetes. Hence, lockdown during COVID-19 pandemic may be associated with poor glycemic control in people with diabetes.

However, there is no evidence set forth for this presumption except for the experiences from the past natural disasters which mimic the similar difficulties and limitations of daily activities [2, 3]. Isolated studies in type 1 diabetes individuals have conflicting reports of worsening or no impact of lockdown period on glycemic control [4–6]. It is also evident that glycemic control may worsen due to the direct effect of SARS-CoV-2 infection in individuals affected, and people with diabetes are likely to have poorer outcomes from SARS-CoV2 infection [7]. Therefore, we prospectively

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studied the effect of lockdown on physical activity and glycemic control in people with pre-existing type 2 diabetes mellitus.

## Materials and methods

We invited 750 participants out of 2240 people with pre-existing type 2 diabetes who were regularly attending diabetes clinic at PGIMER, Chandigarh, prior to COVID-19 lockdown and had access to home-based capillary glucose monitoring by glucometer during the lockdown period. We have complete demographic and disease-related detail in electronic case record system. Patients with type 1 diabetes, incomplete records, or not having facility for self-monitoring of blood glucose during the lockdown period or not accessible for tele-medicine counselling or consultation and COVID-positive patients were excluded from the study.

Their demographic characteristics, duration of diabetes, physical activity, microvascular and macrovascular complications, and glycemic parameters including HbA1c were evaluated and entered in the electronic database at each follow-up visits. Subsequently, the scheduled visits to the hospital were not possible due to lockdown; therefore, they were approached telephonically for consultation and guidance for titration of the medication doses including oral anti-diabetic drugs and/or insulin. They were requested to share glycemic records of fasting (FBG) and postprandial (1–2 h after major meal) blood glucose (PPBG) by home available glucometers and obtain HbA1c at the nearest available laboratory facility after a minimum of 3-month duration of lockdown.

The physical activity pattern of the participants during lockdown was enquired telephonically by Global Physical Activity Questionnaire (GPAQ) that has been validated earlier in Indian population [8, 9] and represented as metabolic equivalents (MetS min/week). Body weight prior to lockdown was obtained from the electronic repository, and weight during lockdown was recorded from the home-based weighing scales or at nearest available health facility. The primary outcome was change in HbA1c, FBG, and PPBG compared to the last observed value before the lockdown in the electronic database. The other outcome measure was the change in GPAQ scores (MetS min/week). The evaluation for micro- and macrovascular complications was performed as per existing protocol of the institute that included annual (more frequently, if needed) fundus examination, neuropathy and vascular assessment, urine protein, creatinine (eGFR) estimation, and fasting lipids.

## Statistical analysis

Data analysis was performed using the Statistical Package of Social Sciences (SPSS) version 23 (IBM Corp, Armonk, NY).

Normality was examined using the Shapiro-Wilk test. The data is expressed as the median and interquartile range (IQR) as most of the data variables were non-parametric. The pre- and post-lockdown glycemic variables were compared using Wilcoxon signed-rank *T* test and Fischer Exact test/Chi-square test for categorical variables. A sub-group analysis by stratifying data according to gender and the presence or absence of foot complications (active pedal ulcer or foot with deformities limiting physical activity) was performed. The correlation between change in glycemic control (HbA1c) with the modification of weight, BMI, and physical activity (GPAQ) during the lockdown period was analysed. The change in HbA1c during the lockdown was considered as dependent variable with the change in FBG, PPBG, weight, BMI, and physical activity (GPAQ) as independent variables.  $p < 0.05$  was considered significant for the study.

## Results

A total of 422 of the 750 individuals (303 male and 119 female) with diabetes responded with the requisite glycemic parameters within the stipulated duration. The median age of the participants was 58 (52 to 64) years, duration of diabetes of 11 (6 to 16) years, and body mass index of 25.6 (22.7 to 28.7). Prevalent microvascular complications include neuropathy in 58.3%, retinopathy in 30.1%, and nephropathy in 27.0% of participants (Table 1). Foot complications were prevailing in 59.7% and atherosclerotic cardiovascular disease in 21.3% of participants. Overall, 22.7% of participants are on insulin, and the rest are on oral anti-diabetic drugs (Fig. 1).

**Table 1** Demographic characteristics and diabetes complication of the studied cohort prior to COVID-19 lockdown

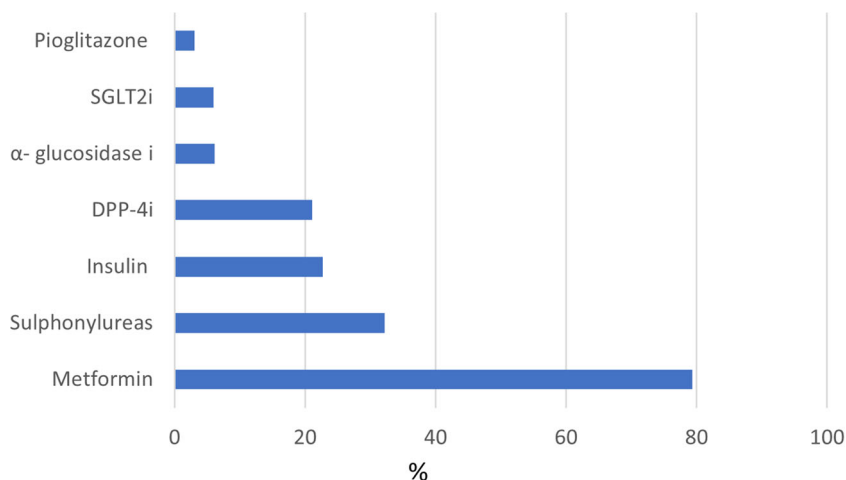
Parameters	Values ( $n = 422$ )
Age (years)	58.0 (52.0 to 64.0)
Duration of diabetes (years)	11.0 (6.0 to 16.0)
Creatinine (mg/dl)	1.03 (0.83 to 1.37)
BMI ( $\text{kg}/\text{m}^2$ )	25.6 (22.7 to 28.7)
Hypertension, $n$ (%)	194 (45.97)
Retinopathy, $n$ (%)	127 (30.09)
Neuropathy, $n$ (%)	246 (58.29)
Nephropathy, $n$ (%)	114 (27.01)
ASCVD, $n$ (%)	90 (21.32)
Foot complication, $n$ (%)	252 (59.71)

Normality of data was checked by Shapiro-Wilk test

Categorical data represented as  $n$  (%) and numerical data as median (interquartile range)

ASCVD atherosclerotic cardiovascular disease; BMI body mass index

**Fig. 1** Various anti-diabetic received by the patients



Last observed HbA1c before COVID-19 lockdown is 7.8 (6.9 to 9.4%), and a HbA1c of 7.4 (6.6 to 8.7) after 3 months of lockdown, with an overall HbA1c reduction of  $0.41 \pm 0.27\%$  ( $p = 0.005$ ) (Table 2). Overall, 35.1% participants had HbA1c < 7%, prior to lockdown as compared to 38.1% 3 months during lockdown ( $p = 0.102$ ). Fasting blood glucose was 135.0 (112 to 175.0) mg/dl and 150.0 (120.0 to 180.0) mg/dl ( $p = 0.02$ ) and postprandial blood glucose of 200.0 (152.0 to 252.0) mg/dl and 158.0 (140.0 to 200.0) mg/dl ( $p < 0.001$ ) before and after 3 months of lockdown, respectively.

We observed a decrease in weight from 72.0 (61.4 to 78.4) kg to 71.0 (62.0 to 80.0) kg ( $p = 0.536$ ) with an increase in physical activity with GPAQ score of 140 (0.0 to 1260) MetS to 840 (0.0 to 1680) MetS ( $p = 0.014$ ). We find no difference in reduction of HbA1c between male and female [ $\Delta$ HbA1c  $-0.6$  ( $-1.5$  to  $1.0$ )% in male and  $-1.1$  ( $-2.2$  to  $0.4$ )% in female ( $p = 0.39$ )] or physical activity GPAQ [ $\Delta$  GPAQ 0.00 (0.00 to 840) MetS in male and 0.0 (0.0 to 1680) MetS in female ( $p = 0.080$ )] as detailed in Table 3. Participants with foot complications constituted more than half (59.7%) of the respondents. Participants with foot complications had a higher baseline

HbA1c 7.9% (6.9 to 9.4) compared to those without foot complications 7.3% (6.6 to 8.3) ( $p = 0.180$ ) with a decrease in HbA1c of  $-0.4\%$  ( $-1.7$  to  $0.9$ ) and  $-0.3\%$  ( $-1.0$  to  $0.5$ ) ( $p = 0.341$ ) in the two groups, respectively (Table 4). We did not find significant correlation between change in glycemic control ( $\Delta$ HbA1c) with either age ( $p = 0.549$ ), duration of diabetes ( $p = 0.416$ ), change in weight ( $p = 0.597$ ), or physical activity by GPAQ scores ( $p = 0.128$ ).

## Discussion

We observed an overall improvement of glycemic parameter in people with long-standing type 2 diabetes associated with an increase in physical activity as assessed with GPAQ score during the lockdown period unlike the conventional belief of worsening of glycemic control and limitation of physical activity. The decline in HbA1c was independent of the increase in physical activity and was observed in either gender and irrespective of the presence or absence of diabetic foot complications.

**Table 2** Alterations in glycemic parameters and physical activity of the studied cohort during the lockdown

Parameters	Pre-lockdown	During lockdown	<i>p</i> value
Weight (kg)	72.0 (61.4 to 78.4)	71.0 (62.0 to 80.0)	0.536
Body mass index (kg/m <sup>2</sup> )	25.8 (22.8–28.9)	25.8 (22.8–28.9)	0.810
HbA1c (%)	7.8 (6.9 to 9.4)	7.4 (6.5 to 8.7)	0.005
mmol/mol	61.7 (51.9 to 79.2)	57.4 (47.5 to 71.6)	
Fasting blood glucose (mg/dl)	135.0 (112.0 to 175.0)	150.0 (120.0 to 180.0)	0.002
Postprandial blood glucose (mg/dl)	200 (152 to 252.0)	158.0 (140.0 to 200.0)	< 0.001
GPAQ score (MetS)	140 (0.0 to 1260)	840 (0.0 to 1680)	0.014

$p < 0.05$  was considered significant. GPAQ Global Physical Activity Questionnaire (GPAQ). MetS (min/week) metabolic equivalents

**Table 3** Alterations in glyceimic parameters and physical activity of the studied cohort during the lockdown stratified by gender

Parameters	Male <i>n</i> = 303	Female <i>n</i> = 119	* <i>p</i> value
Weight-PL (kg)	73.2 (63.0 to 83.0)	65.0 (60.0 to 75.6)	0.000
Weight-DL (kg)	72.0 (64.0 to 82.0)	68.0 (60.8 to 75.0)	0.003
<i>p</i> value	0.170	0.805	
Δ weight	0.0 (− 5.7 to 3.2)	1.00 (− 1.5 to 11.4)	0.020
HbA1C-PL (%)	7.7 (6.8 to 8.9)	7.6 (6.7 to 9.1)	0.819
mmol/mol	60.7 (50.8 to 73.8)	59.6 (49.7 to 76.7)	
HbA1C-DL (%)	7.3 (6.5 to 8.4)	7.5 (6.6 to 9.0)	
mmol/mol	56.3 (47.5 to 68.3)	58.5 (48.6 to 74.9)	0.420
<i>p</i> value	0.134	0.789	
ΔHbA1C (%)	− 0.6 (− 1.6 to 1.0)	− 1.1 (− 2.2 to 0.4)	0.390
FBG-PL (mg/dl)	130.0 (105.5 to 175.0)	137.4 (110.0 to 187.5)	0.315
FBG-DL (mg/dl)	150.0 (120.0 to 187.0)	152.50(152.5 to 198.5)	0.768
<i>p</i> value	0.004	0.039	
ΔFBG (mg/dl)	23.0 (− 17.1 to 68.0)	− 20.0 (− 37.5 to 49.0)	0.487
PPBG-PL (mg/dl)	191.0 (148.0 to 258.0)	234.5 (157.5 to 250.5)	0.292
PPBG-DL (mg/dl)	155.0 (140.0 to 195.0)	155.0 (131.5 to 242.5)	0.336
<i>p</i> value	0.000	0.160	
ΔPPBG (mg/dl)	− 20.0 (− 78.50 to 44.00)	− 22.0 (− 90.0 to 99.00)	0.751
GPAQ-PL (MetS)	420.0 (0.0 to 1680)	780.0 (0.0 to 1680)	0.524
GPAQ-DL (MetS)	840.0 (0.0 to 1680)	840.0 (0.0 to 1680)	0.362
<i>p</i> value	0.196	0.000	
Δ GPAQ	0.0 (0.0 to 840)	0.0 (0.0 to 560)	0.080

Data represented as median (IQR) and comparison done by Mann-Whitney *U* test. *PL* pre-lockdown; *DL* during lockdown; *FBG* fasting blood glucose; *PPBG* postprandial blood glucose *GPAQ* Global Physical Activity Questionnaire (*GPAQ*); *MetS* metabolic equivalents; Δ last observed value prior to lockdown—value during lockdown *p* value: intragroup comparison; \**p* value, intergroup comparison

COVID-19 pandemic has necessitated lockdown to limit the SARS-CoV2 infection and shown to be effective in reducing the  $R_0$ , i.e. number of people infected by each infected person [10]. While lockdown slows the spread of infection, it is likely to have adverse influence on lifestyle patterns contributing to weight gain. A failure to adhere to lifestyle recommendations for diabetes during lockdown due to a significant curb of outdoor physical activity along with psychological stress related to pandemic may be associated with worsening of glyceimic control. The stress of acquiring COVID has also been ascribed as one of the reasons for poor glyceimic control. A predictive modelling using a simulation model created with the aid of a multivariate regression analysis has shown that the predicted increment in HbA1c from baseline at the end of 30 days and 45 days lockdown could be 2.26 and 3.68%, respectively [11]. However, this prediction was based on data from similar natural disasters but not exactly the same scenario as COVID-19 lockdown and is likely to overestimate the risk because of model-based risk prediction. A cross-sectional study in type 1 diabetes individuals observed an increase in average blood glucose  $276.9 \pm 64.7$  mg/dl as compared to  $212.3 \pm 57.9$  mg/dl and HbA1c of  $10 \pm 1.5\%$  compared to  $8.8 \pm 1.3\%$  ( $p < 0.05$ ) during and before lockdown, respectively [4]. The major reason

attributed to worsening of glyceimic control was the non-availability of insulin in rural and semi-urban areas.

We prospectively studied glyceimic parameters in people with diabetes along and a change in their physical activity consequent to lockdown. Unlike the belief, we observed an improvement in glyceimic parameters compared to the last available pre-lockdown with a significant reduction in HbA1c and postprandial blood glucose after a minimum of 3 months of lockdown. There was an increase in fasting blood glucose but an overall decrease in HbA1c that was likely contributed by a considerable decrease in postprandial blood glucose during the lockdown phase. Our results are consistent with recent studies predominantly in type 1 diabetes people that noticed no effect of lockdown on glyceimic control [5, 6]. Italian authors observed a decrease in time spent in hypoglycemia (time below range) during lockdown in insulin-treated people [5]. The possible reasons for better glyceimic control in our study could be a decrease in work-related stress, adequate time for self-care, better compliance to medications, adherence to dietary recommendations (home cooked food), lack of availability of outside calorie-dense diet, and an increase in physical activity though indoors. Though Ghosh et al. observed an increase in carbohydrate consumption and snacking

**Table 4** Alterations in glycemic parameters and physical activity of the studied cohort during the lockdown stratified by the presence or absence of foot complications

Parameter	With foot complications <i>n</i> = 252	Without foot complications <i>n</i> = 170	* <i>p</i> value
Weight-PL (kg)	72.6 (61.5 to 81.7)	67.7 (62.0 to 78.5)	0.187
Weight-DL (kg)	70.9 (61.7 to 80.0)	68.0 (62.0 to 77.5)	0.579
<i>P</i> value	0.339	0.863	
Δ weight	0.0 (− 3.6 to 2.0)	0.0 (− 1.1 to 1.3)	0.490
HbA1C-PL (%)	7.9 (6.9 to 9.4)	7.3 (6.6 to 8.3)	0.180
mmol/mol	62.8 (51.9 to 79.2)	56.3 (48.6 to 67.2)	
HbA1C-DL (%)	7.6 (6.5 to 9.6)	7.1 (6.4 to 8.0)	0.020
mmol/mol	59.6 (47.5 to 81.4)	54.1 (46.4 to 63.9)	
<i>p</i> value	0.164	0.211	
ΔHbA1C	− 0.4 (− 1.7 to 0.9)	− 0.3 (− 1.0 to 0.5)	0.341
FBG-PL (mg/dl)	131.0 (106.2 to 175.7)	135.5 (105.2 to 176.5)	0.965
FBS-DL (mg/dl)	150.0 (120.0 to 188.2)	132.5 (104.0 to 157.7)	0.587
<i>p</i> value	0.000	0.000	
ΔFBG(mg/dl)	16.0 (− 29.75 to 64.0)	− 10.5 (− 36.7 to 22.5)	0.287
PPG-PL (mg/dl)	196.5 (151.2 to 254.2)	221.0 (144.7 to 304.2)	0.579
PPBG-DL (mg/dl)	157.5 (140.0 to 200.0)	154.5 (127.5 to 171.7)	0.000
<i>p</i> value	0.000	0.099	
ΔPPBG (mg/dl)	− 21.5 (87.5 to 36.5)	− 68.5(139.7 to 8.2)	0.889
GPAQ PL(MetS)	2.0 (0.0 to 1260)	840 (141.0 to 1680)	0.000
GPAQ-DL(MetS)	420 (0.0 to 1680)	1200 (490 to 1680)	0.001
<i>P</i> value	0.004	0.488	
Δ GPAQ	0.0 (0.0 to 720)	0.0 (− 560 to 560)	0.864

Data represented as median (IQR) and intergroup comparison performed by Mann-Whitney *U* test. *PL* pre-lockdown; *DL* during lockdown *FBG* fasting blood glucose; *PPBG* postprandial blood glucose; *GPAQ* Global Physical Activity Questionnaire (GPAQ); *MetS* metabolic equivalents; Δ last observed value prior to lockdown—value during lockdown *p* value, intragroup comparison; \**p* value, intergroup comparison

in people with type 2 diabetes from north India [12], recurrent contact through teleconsultations may have helped in allaying fear and stress of acquiring COVID in the present cohort.

Excessive sedentary behavior and lack of exercise are a problem area in management of diabetes due to lack of adherence which is likely to be further worsened by COVID-19 pandemic. However, we observed that most of the respondents engaged themselves in physical activity doing household chores and indoor exercise consequent upon availability of time that was reflected in a significant increase in GPAQ scores during the lockdown. All the respondents were motivated individuals having long duration of diabetes, attending diabetes clinic regularly, and were knowledgeable of lifestyle recommendations and glycemic targets. Moreover, they were regularly counselled telephonically and encouraged to limit calorie intake and sedentary behavior during lockdown. It has been observed that unstructured physical activity like performing household chores is known to help in weight management, controlling postprandial hyperglycemia, and overall improved glycemic control by reducing the total sedentary time, increasing the energy expenditure that may [13, 14]. Thus, despite a significant limitation of outdoor activities

during lockdown, an increase in GPAQ scores suggests that increasing indoor activities and limiting sedentary time are also beneficial for people with diabetes in improving glycemic control.

Our results also suggest that people with significant comorbidities of diabetes that limit outdoor activities like foot complications are also able to achieve good glycemic control. Knowing that people with foot complications like neuropathic foot ulcers or Charcot neuroarthropathy and foot deformities are likely to have higher mortality as compared to individuals with diabetes without foot complications [15, 16], good glycemic control in this cohort is more desirable. The improvement in glycemic parameters associated with an increase in physical activity and weight loss was observed irrespective of gender. COVID-19 is associated with significant psychosocial impact on people with type 2 diabetes related to concerns about worsening of glycemic control. However, improvement noticed in glycemic control in the present study will help to counsel the patients for better self-care during COVID-19 pandemic [17].

This is the first large, prospective study amongst people with long-standing type 2 diabetes to assess the effect of more



than 3 months duration of lockdown on glycemic control. However, certain potential biases cannot be ruled out in the present study including that all the respondents in our study were self-motivated, had long duration of diabetes (> 10 years), were under clinic follow-up for long duration, and aware of lifestyle recommendations and glycemic goals. Moreover, only the motivated patients are likely to respond with glycemic parameters that might have contributed to most patients having improved glycemic control.

During lockdown, GPAQ survey was conducted telephonically; various kinds of glucometers were used for capillary glucose that might have an inherent bias. The reliability and reproducibility of the home-based weighing scales cannot be vouched, but it helped us in understanding the trend of weight change in real life pandemic situation. The dietary change, macronutrient composition, and calorie intake were not recorded. The results of our study may not be generalized to those with shorter duration of diabetes or with limited healthcare teleconsultation access.

In conclusion, the present study assures that lockdown period may not be associated with worsening of glycemic control in people with long-standing diabetes. Limiting sedentary time and increasing indoor activities also help in achieving better glycemic control during COVID-19 lockdown. Awareness of glycemic goals, access to self-monitoring of blood glucose, and ability to cope with restrictions of lockdown by rigorously following lifestyle recommendations and engagement in some form of physical activity are beneficial.

**Acknowledgments** We thank Miss Raveena, Mrs. Kusum, and Mrs. Reshma for data collection.

### Compliance with ethical standards

**Conflict of interest** None.

**Informed consent** A written informed consent was obtained from all participants (signed digitally) and the study was approved by the institute Ethics Committee.

### References

- Alfano V, Ercolano S. The efficacy of lockdown against COVID-19: a cross-country panel analysis. *Appl Health Econ Health Policy*. 2020;18(4):509–17. <https://doi.org/10.1007/s40258-020-00596-3>.
- Fonseca VA, Smith H, Kuhadiya N, Leger SM, Yau CL, Reynolds K, et al. Impact of a natural disaster on diabetes. *Diabetes Care*. 2009;32:1632e8.
- Fujihara K, Saito A, Heianza Y, Gibo H, Suzuki H, Shimano H, et al. Impact of psychological stress caused by the great East Japan earthquake on glycemic control in patients with diabetes. *Exp Clin Endocrinol Diabetes*. 2012;120(9):560e3.
- Verma A, Rajput R, Verma S, Balania VKB, Jangra B. Impact of lockdown in COVID19 on glycemic control in patients with type 1 diabetes mellitus [published online ahead of print, 2020 Jul 13]. *Diabetes Metab Syndr*. 2020;14(5):1213–6. <https://doi.org/10.1016/j.dsx.2020.07.016>.
- Beato-Vibora PI. No deleterious effect of lockdown due to COVID-19 pandemic on glycaemic control, measured by glucose monitoring, in adults with type 1 diabetes. *Diabetes Technol Therapeut*. 2020. <https://doi.org/10.1089/dia.2020.0184>.
- Maddaloni E, Coraggio L PS, Carlone A, Pozzilli P, Buzzetti R. Effects of COVID-19 lockdown on glucose control: continuous glucose monitoring data from people with diabetes on intensive insulin therapy. *Diabetes Care*. 2020;6:dc200954. <https://doi.org/10.2337/dc20-0954>.
- Bornstein SR, Rubino F, Khunti K, Mingrone G, Hopkins D, Birkenfeld AL, et al. Practical recommendations for the management of diabetes in patients with COVID-19. *Lancet Diabetes Endocrinol*. 2020;8(6):546–50. [https://doi.org/10.1016/S2213-8587\(20\)30152-2](https://doi.org/10.1016/S2213-8587(20)30152-2).
- Cleland CL, Hunter RF, Kee F, Cupples ME, Sallis JF, Tully MA. Validity of the global physical activity questionnaire (GPAQ) in assessing levels and change in moderate-vigorous physical activity and sedentary behavior. *BMC Public Health*. 2014;14:1255–65.
- Anjana RM, Pradeepa R, Shukla KD, et al. Physical activity and inactivity pattern in India result from the ICMR-INDIAB study (Phase-1): IJBNPA. *Org*. 2014;11:1–26.
- Rawson T, Brewer T, Veltcheva D, Huntingford C, Bonsall MB. How and when to end the COVID-19 lockdown: an optimization approach. *Front Public Health*. 2020;8:262. Published 2020 Jun 10. <https://doi.org/10.3389/fpubh.2020.00262>.
- Ghosal S, Sinha B, Majumder M, Misra A. Estimation of effects of nationwide lockdown for containing coronavirus infection on worsening of glycosylated haemoglobin and increase in diabetes-related complications: a simulation model using multivariate regression analysis. *Diab Metabol Syn Clin Res Rev*. 2020;14:319–23.
- Ghosh A, Arora B, Gupta R, Anoop S, Misra A. Effects of nationwide lockdown during COVID-19 epidemic on lifestyle and other medical issues of patients with type 2 diabetes in North India [published online ahead of print, 2020 Jun 2]. *Diabetes Metab Syndr*. 2020;14(5):917–20.
- Levine JA, McCrady SK, Lanningham-Foster LM, Kane PH, Foster RC, Manohar CU. The role of free-living daily walking in human weight gain and obesity. *Diabetes*. 2008;57:548–54.
- Dunstan DW, Kingwell BA, Larsen R, et al. Breaking up prolonged sitting reduces post-prandial glucose and insulin responses. *Diabetes Care*. 2012;35:976–83.
- Rastogi A, Goyal G, Kesavan R, Bal A, et al. Long term outcomes after incident diabetic foot ulcer: multicenter large cohort prospective study (EDI-FOCUS investigators) epidemiology of diabetic foot complications study. *Diab Res Clin Pract*. 2020;162:108113. <https://doi.org/10.1016/j.diabres.2020.108113>.
- Chaudhary S, Bhansali A, Rastogi A. Mortality in Asian Indians with Charcot's neuroarthropathy: a nested cohort prospective study. *Acta Diabetol*. 2019;56:1259–64. <https://doi.org/10.1007/s00592-019-01376-9>.
- Singhai K, Swami MK, Nebhinani N, Rastogi A, Jude E. Psychological adaptive difficulties and their management during COVID-19 pandemic in people with diabetes mellitus. *Diab Metab Syndrom: Clin Res Rev*. 2020;14:1603–5.

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