# Stay-at-Home Orders During the COVID-19 Pandemic, an Opportunity to Improve Glucose Control Through Behavioral Changes in Type 1 Diabetes

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**OBJECTIVE**

**To investigate the impact of coronavirus disease 2019 lockdown on glycemic control and associated factors in people living with type 1 diabetes.**

**RESEARCH DESIGN AND METHODS**

**An observational evaluation from a self-reported questionnaire on behavioral changes and glycemic information from flash glucose monitoring (FGM) during the lockdown in 1,378 individuals living with type 1 diabetes who used a French dedicated nationwide web application (CoviDIAB).**

**RESULTS**

**The main outcome was the change of the mean glucose level 2 months before and 1 month after the lockdown. We found that mean glucose improved from 9.1 ± 1.7 mmol/L to 8.7 ± 1.7 mmol/L ($P$ < 0.001). Factors associated with better glycemic control were a decrease of alcohol consumption (odds ratio [OR] 1.75 [95% CI 1.04–2.94]), an increase in the frequency of FGM scans (OR 1.48 [1.04–2.10]) and in the number of hypoglycemia events (OR 1.67 [1.13–2.46]), and an easier diabetes control perception (OR 1.71 [1.18–2.49]).**

**CONCLUSIONS**

**Our findings suggest that lockdown has a positive impact on glycemic control in people with type 1 diabetes.**

Given the spread of coronavirus disease 2019 (COVID-19), lockdown was ordered in France on 17 March 2020. Stay-at-home recommendations were reinforced for people with diabetes. This announcement, the challenge to manage their treatment, and the difficulty to contact their caregivers increased anxiety in this population. However, whether the lockdown and behavioral changes induced by it could impact glycemic control in people with diabetes is not clear. We aim, in this study, to analyze the impact of the lockdown on glycemic control in type 1 diabetes.

## RESEARCH DESIGN AND METHODS

To provide support and information to patients with diabetes during the lockdown, the Federation of Diabetology in Paris (Assistance Publique-Hôpitaux de Paris) opened a web application, www.CoviDIAB.fr, a specialized social medium freely

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available nationwide upon registration. The service was interactive and included live sessions, quizzes related to COVID-19 symptoms, and more extensive questionnaires on diabetes. The questionnaire analyzed here was submitted to the participants 38 days after the beginning of the lockdown in France (23 April 2020, reply before 28 April 2020) and collected behavior information regarding lifestyle and treatment before and during the lockdown and glucose control information (mean glucose and time in range) retrieved from the flash glucose monitoring (FGM) devices, if available. Participants registered to CoviDIAB gave consent for anonymized data analysis in accordance with the European General Data Protection Regulation. The study was declared to and authorized by the French data protection committee, Commission Nationale Informatique et Liberté (CNIL, authorization No. 2218292v0), and was approved by the Institutional Review Board (authorization number IRB 00006477) from the local Scientific and Ethical Committee (CEERB Paris Nord, Paris, France). All subjects included in this study were informed about the use of their data for research, and subjects who objected to the reuse of their data were excluded from this study, in accordance to French legislation.

We included in this study people with self-reported type 1 diabetes equipped with an FGM device. We excluded those with missing data regarding FGM data.

The main outcome was the difference between glycemic control before and during the lockdown period. To assess glycemic control, we used the mean glucose from the FGM, assuming FGM mean glucose for the last 30 days (meanG30days) at time the questionnaire was completed to be representative of the control during the lockdown. Mean glucose for the last 90 days (meanG90days) was also available. We estimated a prelockdown mean (meanGpre-lockdown) equal to (3 × meanG90days − meanG30days)/2. Mean glucose was used rather than time in range because the self-reported questionnaire did not allow us to check whether the target range was set according to the international recommendations (1). We analyzed the factors associated with the change in glycemic control using the difference of meanGpre-lockdown − meanG30days as a surrogate. We compared questionnaire answers between participants above (degradation of glycemic control) and below (improvement of glycemic control) the median of this difference.

Differences between groups were assessed using the $\chi^2$ test and the Student $t$ test. To assess factors associated with improvement of glycemic control, we also performed a logistic regression analysis including parameters with $P < 0.10$ in the comparison between groups. As a sensitivity analysis, we also compared participants with or without improvement ≥10% of mean glucose. All data were analyzed using R version 3.6.3 software (R Project for Statistical Computing). A $P$ value <0.05 was considered significant.

## RESULTS

Among the 5,476 participants registered to the CoviDIAB web application, 1,378 participants with type 1 diabetes and complete self-reported FGM data were included for analysis. The median age was 46 (interquartile range 35–56) years, 866 (62.8%) were women, and the median BMI was 24.6 kg/m$^2$ (22.1–27.7). Only 136 participants (9.9%) kept a normal professional activity outside the home, while the others stayed home during the lockdown.

Overall, glycemic control improved during the lockdown, on average, from 163.5 ± 31.2 mg/dL (9.1 ± 1.7 mmol/L) to 155.7 ± 30.3 mg/dL (8.7 ± 1.7 mmol/L) ($P < 0.001$). Comparison between participants below (worse control) and above (improved control) the median of change is presented in Table 1. Briefly, those with improved control were younger, had a higher prelockdown HbA$_{1c}$, and had a higher anxiety score before the lockdown. They consumed less food during the lockdown, with more frequent "moderate weight loss" (1–3 kg), and also declared frequent prelockdown snacking and reduced snacking during the lockdown. They started more frequent physical activity during the lockdown (endurance and muscular strength), scanned more often, and administered less extra insulin, presumably because of a lesser need of it. In logistic regression analysis, factors positively and significantly associated with improvement of glucose control were a decrease of alcohol consumption (odds ratio [OR] 1.75 [95% CI 1.04–2.94]), an increase in the frequency of FGM scans (OR 1.48 [1.04–2.10]) and in the number of hypoglycemia events (OR 1.67 [1.13–2.46]), and an easier diabetes control perception during the lockdown (OR 1.71 [1.18–2.49]). In a sensitivity analysis, similar associations were observed using 10% improvement as an outcome as well as time-in-range values (data not shown).

## CONCLUSIONS

In this study of self-reported glycemic profile and daily habits during the lockdown of 1,378 people living with type 1 diabetes, we showed that glycemic control improved during lockdown on average. The improvement was associated with a range of behavioral changes. All are related to positive lifestyle changes such as improvement of eating patterns along with the increase of physical activity. The lesser need of extra insulin injections associated with improved glucose control suggests a more stable rhythm of life. In line with previous studies, we also observed that frequency of FGM scans was positively associated with better glycemic control (2,3).

Recent reports documented related issues, with small numbers of participants recruited in a few expert centers; however, these reports led to conflicting results (4–7). In 207 adults with type 1 diabetes wearing a continuous glucose monitoring device, Capaldo et al. (6) found that time in range increased from 55.6% to 58.2% during the 2-month period of the lockdown in Italy compared with the preceding 2 months. Of note, the authors did observe a significant and consistent relationship between physical activity and improved markers of glucose control, potentially a statistical power issue. Conversely, Maddaloni et al. (7) did not find any significant changes in the ambulatory glucose profile of 55 insulin-treated adults (90% with type 1 diabetes). However, the study was limited to the first 14 days of the lockdown, which might be too short to observe an impact of lockdown-induced lifestyle changes on the glucose profile. Taken together, these findings and the current work with a much larger sample size suggest that lockdown could have a positive consequence through decreased workloads and increased time to cope with daily challenges of diabetes management.

Our study has some limitations. Above all, the self-reported nature of the questionnaire led to obvious biases. However, the collection of cloud-stored data would

**Table 1—Comparison of participants above and below the median difference between mean glucose prelockdown and mean glucose for the last 30 days before questionnaire**

| | Overall $N = 1,378$ | Below median (degradation of glucose control) $n = 689$ | Above median (improved glucose control) $n = 689$ | $P$ |
|---|---|---|---|---|
| Female sex | 866 (62.8) | 423 (61.4) | 443 (64.3) | 0.13 |
| Age (years) | 45.6 ± 13.6 | 46.6 ± 13.7 | 44.6 ± 13.5 | 0.014 |
| BMI (kg/m$^2$) | 25.2 ± 4.5 | 25.0 ± 4.3 | 25.4 ± 4.7 | 0.13 |
| Smoking | 300 (21.8) | 134 (19.4) | 166 (24.1) | 0.11 |
| Number of pump users | 221 (16.0) | 118 (17.1) | 103 (14.9) | 0.27 |
| Prelockdown $HbA_{1c}$ (%) | 7.4 ± 1.0 | 7.4 ± 1.0 | 7.5 ± 0.9 | 0.002 |
| Prelockdown $HbA_{1c}$ (mmol/mol) | 57 ± 3 | 57 ± 3 | 58 ± 3 | |
| Scores at the start of the lockdown | | | | |
| Anxiety score | 6.1 ± 3.1 | 5.9 ± 3.0 | 6.3 ± 3.2 | 0.011 |
| Depression score | 5.0 ± 3.7 | 4.9 ± 3.7 | 5.1 ± 3.7 | 0.29 |
| Smoking change | | | | 0.50 |
| Quit | 117 (10.7) | 63 (11.4) | 54 (10.0) | |
| Decreased | 59 (5.4) | 28 (5.1) | 31 (5.7) | |
| Stable | 829 (75.6) | 423 (76.4) | 406 (74.9) | |
| Increased | 91 (8.3) | 40 (7.2) | 51 (9.4) | |
| Food consumption change | | | | 0.006 |
| Decreased | 287 (21.0) | 124 (18.2) | 163 (23.9) | |
| Stable | 822 (60.3) | 414 (60.6) | 408 (59.9) | |
| Increased | 255 (18.7) | 145 (21.2) | 110 (16.2) | |
| Prelockdown snacking | | | | 0.011 |
| No | 697 (50.6) | 377 (54.7) | 320 (46.4) | |
| Small frequency | 609 (44.2) | 284 (41.2) | 325 (47.2) | |
| Frequent | 66 (4.8) | 26 (3.8) | 40 (5.8) | |
| Snacking change during lockdown | | | | 0.004 |
| Decreased | 216 (16.0) | 86 (12.7) | 130 (19.2) | |
| Stable | 822 (60.8) | 420 (62.2) | 402 (59.4) | |
| Increased | 314 (23.2) | 169 (25.0) | 145 (21.4) | |
| Alcohol consumption before lockdown (number of glasses/day) | | | | 0.30 |
| ≤1 | 975 (71.8) | 494 (72.9) | 481 (70.8) | |
| 1–2 | 308 (22.7) | 154 (22.7) | 154 (22.7) | |
| 3 | 49 (3.6) | 18 (2.7) | 31 (4.6) | |
| >3 | 25 (1.8) | 12 (1.8) | 13 (1.9) | |
| Alcohol consumption change during lockdown | | | | 0.07 |
| Decreased | 137 (10.6) | 56 (8.7) | 81 (12.4) | |
| Stable | 972 (74.9) | 498 (77.3) | 474 (72.6) | |
| Increased | 188 (14.5) | 90 (14.0) | 98 (15.0) | |
| Sleep quality change during lockdown | | | | 0.10 |
| Degradation | 547 (39.9) | 280 (41.0) | 267 (38.9) | |
| Stable | 663 (48.4) | 336 (49.2) | 327 (47.6) | |
| Improvement | 160 (11.7) | 67 (9.8) | 93 (13.5) | |
| Physical activity change during lockdown | | | | 0.007 |
| Decreased | 673 (49.2) | 348 (51.0) | 325 (47.4) | |
| Stable | 344 (25.1) | 184 (27.0) | 160 (23.3) | |
| Increased | 351 (25.7) | 150 (22.0) | 201 (29.3) | |
| Endurance activities | 532 (38.6) | 234 (34.0) | 298 (43.3) | 0.001 |
| Muscular strength activities | 414 (30.0) | 171 (24.8) | 243 (35.3) | <0.001 |
| Weight change during lockdown | | | | 0.03 |
| Loss of >3 kg | 15 (1.1) | 4 (0.6) | 11 (1.6) | |
| Loss of 1–3 kg | 171 (12.4) | 70 (10.2) | 101 (14.7) | |
| Stable | 762 (55.3) | 404 (58.6) | 358 (52.0) | |
| Gain of 1–3 kg | 369 (26.8) | 180 (26.1) | 189 (27.4) | |
| Gain of >3 kg | 49 (3.6) | 26 (3.8) | 23 (3.3) | |
| Access to caregivers | | | | 0.28 |
| Degradation | 140 (10.6) | 73 (11.0) | 67 (10.2) | |
| Stable | 337 (25.5) | 180 (27.1) | 157 (23.8) | |
| Improvement | 845 (63.9) | 410 (61.8) | 435 (66.0) | |

*Continued on p. 842*

Table 1—Continued

| | Overall $N = 1,378$ | Below median (degradation of glucose control) $n = 689$ | Above median (improved glucose control) $n = 689$ | $P$ |
|---|---|---|---|---|
| Extra insulin injection change during lockdown | | | | <0.001 |
| Decreased | 239 (17.6) | 85 (12.5) | 154 (22.8) | |
| Stable | 610 (45.0) | 314 (46.2) | 296 (43.8) | |
| Increased | 488 (36.0) | 274 (40.4) | 214 (31.7) | |
| Missing rapid insulin injection change during lockdown | | | | 0.24 |
| Decreased | 127 (9.4) | 70 (10.3) | 57 (8.4) | |
| Stable | 1,214 (89.7) | 599 (88.5) | 615 (91.0) | |
| Increased | 12 (0.9) | 8 (1.2) | 4 (0.6) | |
| Frequency of hypoglycemia change during lockdown | | | | <0.001 |
| Decreased | 309 (22.5) | 187 (27.2) | 122 (17.7) | |
| Stable | 713 (51.9) | 379 (55.2) | 334 (48.5) | |
| Increased | 353 (25.7) | 121 (17.6) | 232 (33.7) | |
| Diabetes control perception during lockdown | | | | <0.001 |
| Harder | 276 (20.1) | 175 (25.5) | 101 (14.7) | |
| Similar | 564 (41.0) | 302 (44.0) | 262 (38.1) | |
| Easier | 535 (38.9) | 210 (30.6) | 325 (47.2) | |
| Scanning frequency change during lockdown | | | | 0.001 |
| Decreased | 83 (6.1) | 44 (6.4) | 39 (5.7) | |
| Stable | 782 (57.0) | 423 (61.5) | 359 (52.6) | |
| Increased | 506 (36.9) | 221 (32.1) | 285 (41.7) | |
| Glycemia | | | | |
| MeanG30days | 155.7 ± 30.3 | 159.3 ± 33.4 | 152.2 ± 26.5 | <0.001 |
| MeanG90days | 160.7 ± 29.8 | 156.5 ± 30.9 | 164.9 ± 28.1 | <0.001 |
| MeanGpre-lockdown | 163.2 ± 31.2 | 155.2 ± 30.6 | 171.3 ± 29.7 | <0.001 |
| MeanG30days − meanGpre-lockdown | 7.5 ± 17.1 | −4.1 ± 13.7 | 19.1 + 11.4 | <0.001 |
| TIR30 | 56.0 ± 17.7 | 55.4 ± 18.5 | 56.5 ± 16.8 | 0.241 |
| TIR90 | 53.2 ± 17.4 | 55.1 ± 18.03 | 51.4 ± 16.6 | <0.001 |

Data are presented as the mean ± SD or *n* (%). Comparisons used the $\chi^2$ test or the Fisher exact test for categorical variables and the Student *t* test, ANOVA test, or the Mann-Whitney-Wilcoxon test, as appropriate, for continuous variables. TIR, time in range (defined between 70 and 180 mg/dL).

have limited the recruitment to more expert patients. Moreover, we had access neither to the coefficient of variability nor to individual ranges necessary to interpret time-in-range, time-below-range, and time-above-range values, all valuable indexes of glucose control beyond mean glucose. Finally, we cannot assume that our results could be generalized to the whole French population living with type 1 diabetes and how participation in the CoviDIAB program could influence the results. Strengths included the large number of participants and the nationwide recruitment, not limited to patients monitored in expert centers.

To conclude, our study suggests that while the lockdown was a source of anxiety for many people with type 1 diabetes, it was also an opportunity to make positive behavioral changes. Their persistence after easing of lockdown should be studied.

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