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Body weight, dietary intake, and health risk factors pre-COVID and during the COVID-19 pandemic

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ABSTRACT

The objective of this study was to assess changes in body weight, body fat, food intake, and clinical risk factors during the 2020 COVID-19 pandemic (COVID group) vs. the pre-COVID period (pre-COVID group). Clinical measurements were collected and Food Frequency Questionnaires (FFQs) were administered at two time points for each group (211 days ± 114 SD). For the pre-COVID group, the data were collected before February 20, 2020. For the COVID group, the data were collected either before and after February 20, 2020, or both between February 20, 2020 and April 1, 2021, excluding a 6.5-month pandemic-related pause of hospital visits. Increases in the following outcome measures were seen in the COVID group relative to the preCOVID group: body weight ($t = 3.40$, $p = 0.004$), body fat mass ($t = 2.29$, $p = 0.024$), diastolic blood pressure (BP) ($t = 2.10$, $p = 0.039$), total cholesterol ($t = 1.81$, $p = 0.074$, marginal), and fat/oil intake ($t = 2.44$, $p = 0.017$). In contrast, there were decreases in fruit intake ($t = -1.88$, $p = 0.064$, marginal) in the COVID group compared to the preCOVID group. The COVID period relative to pre-COVID was associated with unfavorable changes in body weight and composition, food intake, and health risk factors. This appears to be the first report of in-person direct measures of changes in body weight and risk factors.

1. Introduction

The COVID-19 pandemic has affected lifestyle behaviors by events such as supply-chain failures and has raised food insecurity for many households (Parekh et al., 2021). In a previous COVID-19 study, we showed that women increased the energy density of food intake during the lockdown period (Poskute et al., 2021). Other studies found self-reported changes in dietary intake during this period. In an Italian sample based on an online questionnaire, 49.6% reported no change in food intake during the lockdown; 46.1% reported eating more, and 19.5% gained weight (Scarmozzino & Visioli, 2020). The respondents reported increased consumption of chocolate, ice cream, and desserts (42.5%) and salty snacks (23.5%). In addition, 42.7% percent attributed this increase to higher anxiety levels (Scarmozzino & Visioli, 2020). Also, a cross-sectional study in Lebanon with an online questionnaire adapted from a 20-food item Short Food Frequency Questionnaire (FFQ) found that 44.7% of participants reported not consuming fruits daily, and 35.3% reported not consuming vegetables daily (Cheikh Ismail et al., 2021).

Cheikh et al. found in Lebanon that 32.8% of respondents reported weight gain, 34.0% no weight change, and 28.9% weight loss during the lockdown (Cheikh Ismail et al., 2021).. Using an online questionnaire in a German student sample, Palmer et al. found that 27% of participants reported weight gain, 23% reported weight loss, and 49% reported increased consumption of sweets and cakes (Palmer et al., 2021). In a cross-sectional study using an FFQ via social media in China (Xu et al., 2021), 18.6% of men and 16.3% of women self-reported weight gain >2.5 kg, and 39.8% of men and 42.1% of women reported no weight change during the lockdown.

Studies in the U.S. have also found self-reported weight gain. In a recent prospective online questionnaire study (Seal et al., 2022), American adults self-reported a 0.6 kg increase in body weight during a 3-month period after stay-at-home mandates, with 18.4% of participants gaining >2 kg compared to the pre-mandate period. In another U.S. study, 269 study participants, using home-based Bluetooth scales, reported weight gain of 0.27 kg every 10 days, but with no comparison group (Lin et al., 2021).

All of these studies had no pre-COVID-19 comparison group. The weight change patterns and dietary intake prior to and during the pandemic were based on self-reported data limited by social desirability,

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with potential response bias and did not provide objective quantitative data about body weight or food intake. The exception was the study by Lin et al., where participants weighed themselves on a scale at home and readings were upload via Bluetooth to an app. However, because of lack of supervision, there could be circumstances, such as wearing heavy clothes, weighing on an uneven surface, or after eating, that could affect the weight data. Moreover, their sample was selectively limited to those who owned a Bluetooth scale versus a conventional scale, or those who do not own scales. Additionally, Lin et al., did not collect quantitative dietary intake data. In our study, trained research personnel weighed the participants after fasting in a controlled environment and collected detailed dietary intake data using the brief Block Food Frequency Questionnaire.

We prospectively investigated body weight and dietary intake of adults in New York City (NYC) before and during the COVID-19 pandemic, beyond the lockdown period, but before vaccination roll-outs for those >16 years old. This study appears to be the first to use supervised measured body weight, detailed dietary intake data, and health risk factor measures during the COVID-19 period with a pre-COVID comparison group. Dietary intake and clinical data were collected from an ongoing NIH-funded supermarket randomized controlled trial (RCT). The study includes a 2-month baseline period, followed by an 8-month intervention period, during which participants are randomized into one of three intervention groups: 0% (control), 15%, and 30% discounts on fruits, vegetables, and non-caloric beverages. There is then a 4-month follow-up period, during which there is no discount. This study took advantage of the COVID-19 natural experiment to investigate the effects of the COVID-19 pandemic on body weight, dietary intake, and clinical measurements relative to the pre-COVID-19 period. The included participants remained in the same phase, i.e., baseline or in a given discount level between the two time points. We predicted that participants during the COVID period would gain more weight (primary measure) and body fat than those during the pre-COVID period. Furthermore, we anticipated that intake of high energy-dense (ED) foods, i.e., snack foods, would increase and low ED foods, i.e., fruits and vegetables, would decrease. We also predicted unfavorable changes to health risk factors, such as blood lipids and blood pressure.

2. Methods

2.1. Study design

Participants for this prospective longitudinal study were drawn from an ongoing NIH-funded RCT. The Institutional Review Board at the Icahn School of Medicine approved the study and consent. Data were collected at two time points for each participant. Participants whose two points were collected before February 20, 2020, were considered the pre-COVID group. We used February 20, 2020 as the boundary because it was a week prior to the following events: the first reported case in NYC, the first COVID19-related death in the U.S., and initial reports of the stockpiling of foods (Goldstein & McKinley, 2020; Schmidt, 2020; Taylor, 2020). Data collected after April 1, 2021, were not included due to the rollout of vaccinations for those age 16 and older (New York State, 2021).

2.2. Participants

Dietary intakes and clinical measurements were assessed at two time points separated on average by 211 days ± 114 (SD). The average number of days between measurements for the two groups were 118 days for the preCOVID group and 302 days for the COVID group. The sample of n = 95 was derived largely from an interim dataset including participants during the baseline and intervention periods. Those whose two time points were prior to February 20, 2020, were considered the pre-COVID-19 group (n = 47). Those whose two time points were either before and after February 20, 2020 (n = 41) or both after February 20, 2020 (n = 7) were considered the COVID-19 group (n = 48). Participant visits to the hospital were suspended for 6.5 months due to COVID-19 from March 18, 2020 until October 2, 2020 (Fig. 1). Participant characteristics are shown in Table 1.

2.3. Protocol

Clinical measures: Participants visited the hospital twice after an overnight fast at about the same time of day. Body weight and height, BMI (kg/m^2), percent body fat, systolic and diastolic blood pressure (mmHg) were obtained by a study nurse and trained research personnel. Blood samples were sent to Quest Diagnostics for analysis of serum fasting glucose (mg/dL), hemoglobin A1c (%), total cholesterol (mg/dL), HDL-cholesterol (mg/dL), LDL-cholesterol (mg/dL), and triglycerides (mg/dL).

Dietary Intake: The 70-food-item Brief Block Food Frequency Questionnaire (FFQ) (Block et al., 1990) was used to assess dietary intake for the previous 2 months to determine changes in dietary intake. Changes in total daily energy intake of food and beverages (kcal), energy density of solid foods (kcal/g), and grams of the following: fruits, vegetables, alcoholic beverages, snack foods (salty and sweet), fats/oils, and total grams of high ED foods (≥ 3.5 kcal/g), and low ED foods (≤ 1.2 kcal/g) were calculated.

2.4. Statistical analysis

RStudio (version 2021.09.1 Build 372) was used to analyze the data. Multiple linear regression was performed to evaluate the effect of the COVID-19 period on the changes in outcomes, while controlling for sex, discount level, age, and the baseline outcome measure. Additional covariates tested included the store the participants were recruited from, household size, the number of days between measurements, annual household income, race, and ethnicity. These variables did not have a significant effect on the dependent variables and did not change the significance of the independent variable, the COVID-19 period, and thus were not included in the final model. Effect size for the COVID period on the dependent variables was calculated using Cohen's f^2, where f^2 = 0.02, 0.15, or 0.35 is considered small, medium, or large, respectively.

2.5. Sample size calculation

For the primary outcome of weight change, we referred to the study by Lin et al. of 269 individuals who reported their weights using a synchronized Bluetooth home scale (Lin et al., 2021). There was a 0.27 kg weight gain every 10 days (95% CI, 0.17–0.38 kg), $P < 0.001$. Using G*power 3.1.9.7 for 0.80 power, two tailed α = 0.05, generated d = 0.307, and a required total sample size, n ≥ 86.

3. Results

Baseline characteristics are shown in Table 1. None of the characteristics differed by group except for ethnicity ($\chi^2 = 6.19$, p = 0.045).

Adjusted mean changes ± SE in clinical measures and dietary intakes are shown in Table 2. There was an increase in body weight in the COVID-19 group (t = 3.40, p = 0.001, $f^2 = 0.14$) relative to the pre-COVID group. This weight gain resulted from an increase in the COVID group (3.01 kg ± 0.77, p = 0.0002) and a nonsignificant decrease in the pre-COVID group (−1.23 kg ± 0.87, p = 0.16, ns), shown in Fig. 2a. Body fat mass increased in the COVID group vs. pre-COVID group (t = 2.29, p = 0.024, $f^2 = 0.06$), resulting from an increase in fat mass for the COVID group (2.76 kg ± 0.72, p = 0.0002) and a nonsignificant change for the pre-COVID group (0.092 kg ± 0.83, p = 0.91, ns) (Fig. 2b). Similarly, BMI increased for the COVID group vs. the pre-COVID group (t = 2.88, p = 0.005, $f^2 = 0.11$) due to an increase in BMI for the COVID group (1.01 kg/m^2 ± 0.28, p = 0.0006) and a

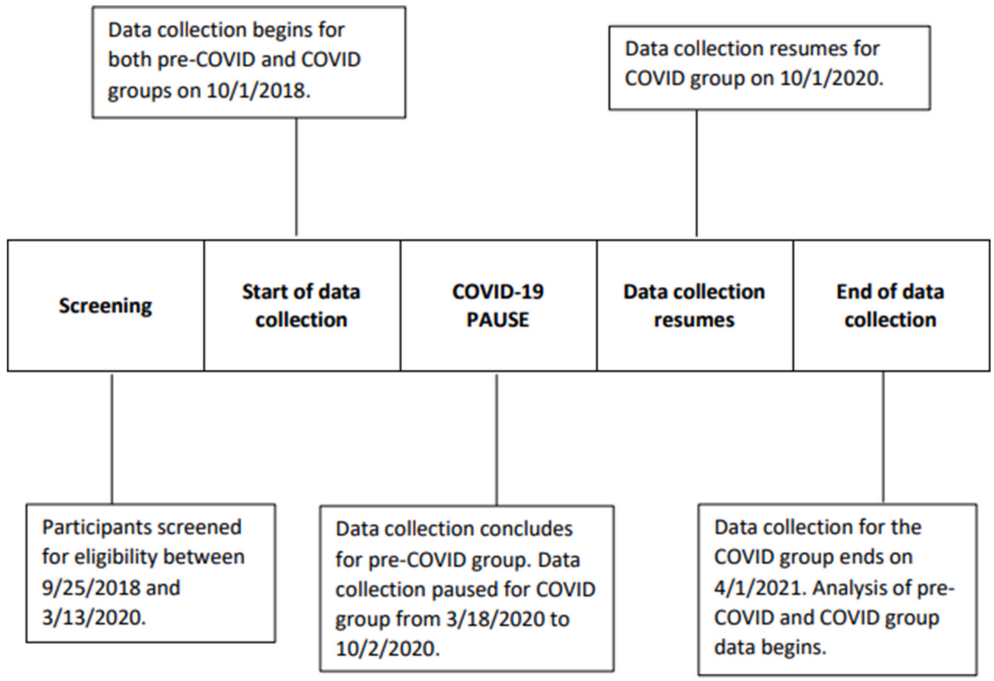

Fig. 1. COVID study data collection timeline.

Table 1
Baseline characteristics for pre-COVID and COVID groups (mean ± SD).

		pre-COVID (n = 47)	COVID (n = 48)
Age		39.1 ± 12.2	39.8 ± 13.6
Body Weight (kg)		84.4 ± 17.2	84 ± 16.7
	Fat-free mass (kg)	56.7 ± 12.3	55.1 ± 10.1
	Fat mass (kg)	27.7 ± 11.6	28.9 ± 14
BMI (kg/m²)		29 ± 4.84	29.5 ± 5.66
Annual Household Income ($)		65,600 ± 47,200	51,700 ± 37,300
Sex	**Female**	29	29
	Male	18	19
Ethnicity	**Hispanic**	7	10
	Non-Hispanic	40	33
	Not provided	0	5
Race	**Asian**	5	3
	Black or African American	11	13
	Native Hawaiian or other Pacific Islander	0	0
	White	23	17
	Mixed	4	3
	Not Provided	1	12

Characteristics did not differ by COVID group except for ethnicity ($\chi2 = 6.19$, $p = 0.045$).

nonsignificant decrease in BMI for the pre-COVID group (−0.30 kg/m^2 ± 0.32, p = 0.34, ns). Mean changes for fat-free mass, and percent fat did not differ significantly between COVID groups.

Diastolic blood pressure showed a relative increase for the COVID group vs. the pre-COVID group (t = 2.10, p = 0.039, $f^2 = 0.02$), associated with a nonsignificant increase for the COVID group (0.86 mm Hg ± 1.15, p = 0.46, ns) and a decrease for the pre-COVID group (−3.02 mm Hg ± 1.30, p = 0.022). The change in systolic blood pressure did not differ significantly between groups.

There were no significant changes in blood level risk factors (Table 2). However, total cholesterol increased marginally in the COVID group vs. the preCOVID group (t = 1.81, p = 0.074, $f^2 = 0.07$), resulting from an increase in total cholesterol for the COVID group (11.36 mg/dL ± 3.35, p = 0.001) vs. no change for the pre-COVID group (1.62 mg/dL ± 3.77, p = 0.67, ns) (Table 2).

Consistent with the pattern for body weight, fat and oil intake increased for the COVID group relative to the pre-COVID group (t = 2.44, p = 0.017, $f^2 = 0.08$). This change resulted from a significant increase in fat and oil intake for the COVID group (5.35 g ± 1.52, p = 0.0007) vs. the pre-COVID group (−0.57 g ± 1.70, p = 0.73, ns) (Fig. 2c). There was a marginally significant change in fruit intake (g) between the two groups (t = −1.88, p = 0.06, $f^2 = 0.02$). This change resulted from a significant decrease in fruit intake (−28.21 g ± 12.3, p = 0.024) for the COVID group vs. no change for the pre-COVID group (8.69 g ± 13.7, p = 0.53, ns) (Fig. 2d). However, the correlations between weight change between groups and oil/fat or fruit change was not significant. All other dietary intake measures did not differ significantly between COVID groups.

4. Discussion

The results showed that the group during the COVID-19 period gained 3 kg, a 4.2 kg increase relative to the preCOVID group, primarily due to an increase in body fat mass as fat-free mass did not change. The COVID group also showed a significant increase in fat and oil intake and a marginally significant decrease in fruit intake, compared to the pre-COVID group. However, we did not observe a similar effect on vegetable intake. There were also relative increases in total cholesterol and diastolic BP. The change in diastolic BP between groups was significant, but mainly derived from a decrease in BP in the pre-COVID group rather than from an increase in the COVID group, likely related to a decrease in body weight in the pre-COVID group (Neter et al., 2003).

Increased oil and fat intake and decreased fruit intake are consistent with the predicted increase in intake of high ED foods and decrease in low ED foods (e.g., fruits), although there was no specific effect on high ED foods. Similarly, there was no significant change in total energy intake, possibly due to the lack of sensitivity of the FFQ, which is subject to potential errors in recall over a period of months. The results are also consistent with our previous finding of increased ED of solid foods, although we did not find an increase in ED in this study. This may be because we used the FFQ here, whereas we used dietary recalls in the previous study. We also covered a period of time during the COVID

Table 2
Changes in clinical measures and dietary intakes within the pre-COVID and COVID groups (Adjusted mean ± SE).

		pre-COVID	COVID	t-value	P-value
Clinical Measures	**Weight (kg)**	−1.2 ± 0.87	3.01 ± 0.77	3.40	0.001*
	Fat-free mass (kg)	−0.26 ± 0.56	0.37 ± 0.48	0.93	0.36
	Fat mass (kg)	0.092 ± 0.82	2.76 ± 0.72	2.29	0.024*
	Percent fat (%)	0.34 ± 0.64	1.31 ± 0.56	1.07	0.29
	BMI (kg/m^2)	−0.30 ± 0.32	1.01 ± 0.28	2.86	0.005*
	Systolic BP (mmHg)	−1.88 ± 2.11	1.55 ± 1.88	1.14	0.26
	Diastolic BP (mmHg)	−3.02 ± 1.30	0.857 ± 1.15	2.10	0.039*
	Fasting Glucose (mg/dL)	1.00 ± 2.28	4.07 ± 2.05	0.97	0.34
	HbA1c (%)	0.006 ± 0.054	−0.065 ± 0.038	−1.0	0.32
	Total Cholesterol (mg/dL)	1.62 ± 3.77	11.36 ± 3.35	1.81	0.074
	HDL-cholesterol (mg/dL)	−3.20 ± 1.36	−0.069 ± 1.20	1.62	0.12
	LDL-Cholesterol (mg/dL)	3.53 ± 3.43	10.66 ± 3.03	1.47	0.15
	Triglycerides (mg/dL)	11.3 ± 7.33	3.7 ± 6.57	−0.72	0.47
Dietary Intake	**Total energy intake (kcal)**	−65.9 ± 86.9	−117.3 ± 77.9	−0.41	0.68
	Energy intake of solid foods (kcal)	−90.7 ± 78.6	−91.0 ± 70.5	−0.003	0.1
	Energy density (ED) of solid food (kcal/g)	0.006 ± 0.046	0.039 ± 0.041	0.51	0.61
	Fruit (g)	8.69 ± 13.7	−28.21 ± 12.3	−1.88	0.064
	Vegetables (g)	−1.59 ± 34.2	7.75 ± 30.7	0.19	0.85
	Sugar-sweetened beverages (g)	20.9 ± 23.2	−20.0 ± 20.9	−1.23	0.22
	Alcohol (g)	10.2 ± 26.2	−26.8 ± 23.2	−0.99	0.33
	Total snack foods (g)	−25.7 ± 7.39	−11.4 ± 6.10	1.47	0.15
	Salty snack foods (g)	−1.88 ± 1.75	1.33 ± 1.57	1.28	0.20
	Sweet snack foods (g)	−23.9 ± 6.79	−11.4 ± 6.10	1.29	0.20
	Fats and oils (g)	−0.57 ± 1.70	5.35 ± 1.52	2.44	0.017*
	High ED solid foods (g)	−6.40 ± 6.12	1.77 ± 5.49	0.93	0.36
	Low ED solid foods (g)	−24.8 ± 41.4	−18.1 ± 37.2	−1.33	0.19

High energy dense (ED) foods ≥3.5 kcal/g, low ED foods ≤1.2 kcal/g.
*P < 0.05.

pandemic beyond the lockdown period for this study as compared to only the lockdown period in the previous study.

Our results with direct in-person longitudinal measurements of fasting body weight and in-person FFQs are largely consistent with cross-sectional studies using self-reported weight and online questionnaires during the lockdown (Cheikh Ismail et al., 2021; Palmer et al., 2021; Scarmozzino & Visioli, 2020; Seal et al., 2022; Xu et al., 2021). Our findings are also consistent with a longitudinal study by Lin et al., using at-home Bluetooth scales, showing increases in body weight. Their weight change was significantly greater than ours, likely due to the fact that the researchers collected weight data during the lockdown period, where stay-at-home orders were in effect.

Our study appears unique in obtaining prospective in-person objective fasting body weight measures at two time points within both a COVID and pre-COVID period. Although the FFQs are self-reported dietary intakes, they were conducted in person during hospital visits and have been well validated (Block et al., 1990). We also included measures of health risk factors, i.e., BP and serum concentrations of HbA1c, fasting glucose, cholesterol, and triglycerides.

Strengths of this longitudinal study include measures of body weight and health risk factors during two in-person hospital visits as well as administered FFQs within the same participants in two groups, one impacted by the COVID-19 pandemic and one pre-COVID. Limitations include the relatively small sample, the lack of post-COVID data, and a lack of physical activity data, which could be a factor in weight gain during the COVID-19 period.

In conclusion, we observed that the COVID group experienced increases in body weight, fat mass, diastolic blood pressure, total cholesterol, fat and oil intake, and a decrease in fruit intake. There is some evidence that increased anxiety during the pandemic may be a contributing factor to weight gain and change in intake (Mattioli et al., 2020; Scarmozzino & Visioli, 2020). Reduced physical activity by staying and working at home may also have contributed to weight gain (Flanagan et al., 2021) These findings may be useful in anticipating the consequences of future pandemics and providing the public with information and guidance to help avoid these consequences.

Ethical statement

Hereby, I Aniema Nzesi, assure that for the manuscript, "Body weight, dietary intake, and health risk factors pre-COVID and during the COVID-19 pandemic", the following is fulfilled:

1) This material is the authors' own original work, which has not been previously published elsewhere.

2) The paper is not currently being considered for publication elsewhere.

3) The paper reflects the authors' own research and analysis in a truthful and complete manner.

4) The paper properly credits the meaningful contributions of co-authors and co-researchers.

5) The results are appropriately placed in the context of prior and existing research.

6) All sources used are properly disclosed (correct citation). Literally copying of text must be indicated as such by using quotation marks and giving proper reference.

7) All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.

The violation of the Ethical Statement rules may result in severe consequences.

To verify originality, your article may be checked by the originality detection software iThenticate. See also http://www.elsevier.com/editors/plagdetect.

I agree with the above statements and declare that this submission follows the policies of Solid State Ionics as outlined in the Guide for Authors and in the Ethical Statement.

Clinical trial registration

Multi-level Supermarket Discount Study, NCT04178824.

Data sharing

De-identified participant summary clinical data, as well as, dietary

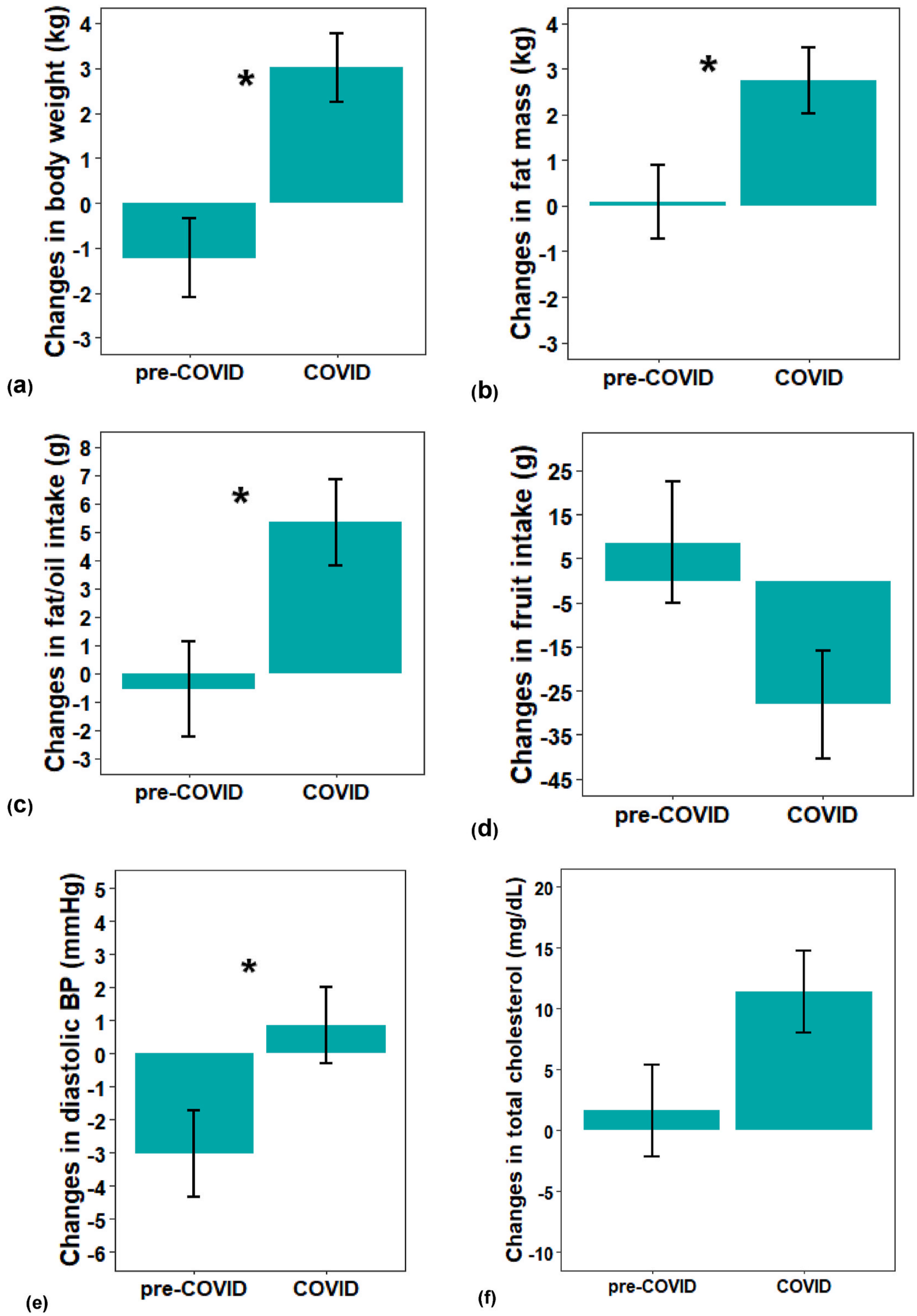

Fig. 2. Adjusted mean changes ± SE between pre-COVID and COVID groups for (**a**) body weight (kg), $p = 0.001$ (**b**) fat mass (kg), $p = 0.024$ (**c**) fat and oil intake (g), $p = 0.017$, and (**d**) fruit intake (g), $p = 0.064$ (**e**) diastolic BP (mmHg), $p = 0.039$ (**f**) total cholesterol, $p = 0.074$.
* $p < 0.05$.

intake data will be shared as requested by other investigators. We will also provide the study protocol and statistical analysis plan.

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Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

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