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Working from home and dietary changes during the COVID-19 pandemic: A longitudinal study of health app (*CALO mama*) users

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ABSTRACT

It is plausible that the coronavirus disease pandemic and related changes in work and life patterns affected dietary patterns, but existing studies have limitations owing to a cross-sectional design. Using longitudinal data, we examined dietary changes in people due to the pandemic and work and life patterns. We conducted an online survey on changes in work and life patterns during the pandemic from April 30, 2020, to May 8, 2020, among users of a health app called *CALO mama* provided in Japan. We retrieved and linked the dietary data for 5929 participants from January 1, 2020, to May 13, 2020. Generalized linear mixed models were used to estimate the frequencies of food intake associated with the pandemic and work and life patterns. During the state of emergency, the frequency of intake of vegetables, beans, seaweeds, fish, meats, dairy products, and snacks increased, whereas alcohol intake decreased. Working from home was associated with increased intake of vegetables, fruits, dairy products, and snacks but decreased intake of seaweeds, meats, and alcohol. Time spent on childcare was associated with decreased intake of vegetables and fruits but increased intake of meats. Probable depressive symptoms were negatively associated with the frequency of food intake other than snacks and alcohol. We conclude that diet quality improved during the pandemic in general, but attention must be paid to overconsumption of snacks and negative factors such as increased burden of childcare and depression for healthy eating.

1. Introduction

To prevent the spread of the coronavirus disease (COVID-19), many countries restricted the movement of people by encouraging them to stay home and strictly refraining them from going to the city. In late March 2020, approximately more than 3.4 billion people in 84 countries were confined to their homes, leading to the growth of work from home (WFH) practice (Bouziri et al., 2020). In Japan, only 8.4% of employees had worked from home as of 2019 (Ministry of Internal Affairs and Communications, 2020); however, during the pandemic, 34.6% of the employees engaged in WFH (Cabinet Office, 2020).

Employment status and working environment can affect dietary patterns (Chau et al., 2017). However, to our knowledge, the effect of WFH on dietary patterns is largely unknown. WFH eliminates the time spent on commute and may enable people to prepare healthy food. A study of American adults reported that those who worked from home spent 1.7 times more minutes cooking and 2.6 times more minutes eating and drinking at home than the average (Restrepo & Zeballos, 2020). In addition, we recently found an inverse association between starting WFH and depressive symptoms during the pandemic (Sato et al., 2021). Depression may decrease appetite and reduce food consumption. Hence, WFH may also contribute to a healthy diet through the pathway of mental health. In contrast, WFH has a tendency to blur the boundaries between work- and home time, and in turn, may lead to longer working hours (Eurofound and the International Labour Office, 2017) and more time being spent on childcare and other housework (Standen et al., 1999), which can tempt people to opt for ready-made and home-delivered meals. In addition, childcare and housework tend to impose more burden on women than men, and such gender differences in roles in a household may modify the association of WFH with dietary

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patterns. As WFH has become prevalent worldwide due to the pandemic, it is important to explore its impact on dietary patterns.

Several researchers have studied dietary changes during the COVID-19 pandemic, but their reports are inconsistent. Some studies reported healthier changes in dietary patterns during the pandemic. An early study in Italy reported increased consumption of vegetables and fruits in a section of the population (Scarmozzino & Visioli, 2020). Another study of adolescents from Spain, Italy, Brazil, Colombia, and Chile reported that the frequency of intake of vegetables, fruits, and legumes increased, while that of fast foods decreased during the confinement (Ruiz-Roso et al., 2020). A study from Spain concluded that the confinement led to adherence to the Mediterranean diet and healthy eating behaviors (Rodríguez-Pérez et al., 2020). In contrast, a study from the US showed a decrease in the consumption of vegetables, fruits, and lean proteins, and an increase in the consumption of red and processed meats and refined grains (Bin Zarah et al., 2020). Similar changes in dietary patterns were found in Poland among those with increased body mass index during quarantine (Sidor & Rzymski, 2020). A study from China also reported that the frequency of intake of fresh vegetables, fruits, soybean products, and dairy products decreased during the lockdown (Jia et al., 2021). Increased consumption of sweets and snacks has been reported consistently (Bin Zarah et al., 2020; Ruiz-Roso et al., 2020; Scarmozzino & Visioli, 2020). However, these studies have a cross-sectional design; thus, they may not provide accurate information on dietary pattern changes before and after the pandemic due to recall bias.

This study used longitudinal data from the users of *CALO mama* health app to examine the change in frequency of intake of various foods during the pandemic. In addition, we explored whether WFH and other routine activities (e.g., working hours, and time spent on childcare and housework) were associated with the change in dietary patterns. We hypothesized that the stay-at-home measure and WFH enhanced consumption of healthy foods at home. However, increased time spent on childcare and housework and mental illnesses due to home-bound lifestyles may negatively affect dietary intake. Therefore, it is necessary to study the dietary changes while considering changes in work and life patterns such as starting WFH, given that the pandemic has been prolonged.

2. Methods

2.1. Study participants

Fig. 1 displays a flow-chart of our analytical sample. From April 30, 2020, to May 8, 2020, we conducted an online survey and invited users of the *CALO mama* health app provided in Japan by Link & Communication Inc. Out of 7061 responses, 6392 consented to have their data used for research purposes. Twenty-nine participants answered the questionnaire twice, and we dropped their older responses. Dietary data were not available for 434 participants from January 1, 2020, to May 13, 2020; thus, our final analytical sample comprised 5929 participants consisting of 1842 men and 4087 women. Their mean age was 44 years old. There were no missing values in responses from the participants. This study was approved by the Research Ethics Committee of the Graduate School of Medicine/Faculty of Medicine, the University of Tokyo (2019372NI-(1)).

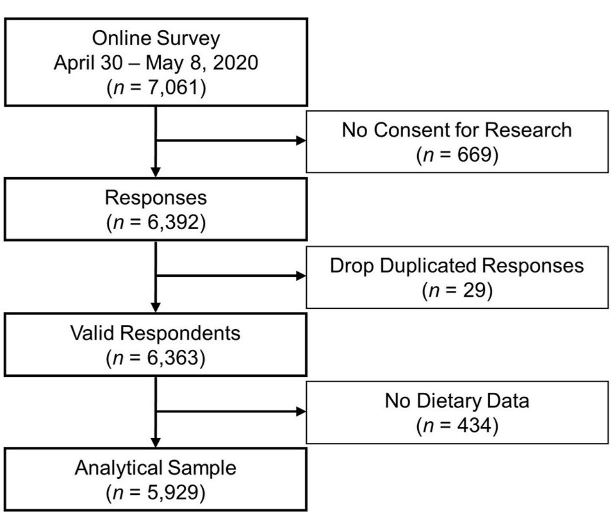

Fig. 1. A flow-chart of the analytical sample.

2.2. Dietary patterns

Fig. 2shows how the app records diet. Users record items of every meal in the app, and artificial intelligence supports accurate recording by detecting photos of the meals taken by the users. The app has about 150,000 foods including fresh food, ready meals, and commercial products by brand name and menu selections from about 450 stores and restaurants. Therefore, the app identifies and records the name of restaurants and manufacturers if a user eats processed food outside of their cooking, at a restaurant, or collects takeaway. In the case of ready-made meals, the nutrition intake is calculated by applying the recorded food items to a standard menu, which is pre-defined based on several recipe books.

We retrieved the dietary data of the participants from January 1, 2020, to May 13, 2020. The Japanese government declared a state of emergency on April 7 and lifted it in 39 of the 47 prefectures on May 14 (three prefectures, lifted on May 21; the remainder, lifted on May 25). Thus, we dichotomized the study period on April 7 and defined the period from January 1 to April 6 and from April 7 to May 13 as the “pre-declaration period” and the “declaration period,” respectively. We used data from weekdays only because most people work on weekdays and the number of holidays was different between the periods (35 days for the pre-declaration period and 14 days for the declaration period), given there are different dietary patterns between weekdays and holidays. Out of 5929 participants, 212 had recorded dietary data during the pre-declaration period only and 1281 during the declaration period only, while the remaining participants recorded data during both periods. To handle this structural imbalance in the data, we used the generalized linear mixed model and included all the 5929 participants in the analyses. In Supplement Figure A, we showed daily trends in the number of total records (i.e., that of participants who recorded their diet in the day) and that of the first record during the study period for each participant. The trend in the number of total records was upward during the study period. Some participants started recording their diet during the study period constantly; thus, the new users appeared to explain the upward trend. Supplement Figure B is a histogram for intervals between dietary records and shows that most dietary records were entered daily. The intervals did not change very much before and after the declaration (see Supplement Table A).

Our primary outcome was the frequency of intake of vegetables, fruits, beans, mushrooms, seaweeds, fish, meats, dairy products, snacks, and alcohol before and after the declaration. We defined the following cut-off values for the weight of each food group in a single item to count as one intake of the food group based on the Japanese Food Guide (Ministry of Agriculture, Forestry and Fisheries, 2005) and the National Health and Nutrition Survey (Ministry of Health, Labour and Welfare, 2020): vegetables ≥70 g, corresponding to one serving of vegetables as per the Japanese Food Guide; fruits ≥50 g, corresponding to the mean intake of fruit per day (52.3 g) as per the National Health and Nutrition Survey (g per 1000 kcal, data from 20 years and older, same as below) and half of one portion of fruit (100 g) as per the Japanese Food Guide; beans ≥20 g, corresponding to the median intake of beans per day (23.1 g) as per the National Health and Nutrition Survey (equivalent to half pack of natto); mushrooms ≥10 g, corresponding to the mean intake of mushrooms per day (8.9 g) as per the National Health and Nutrition

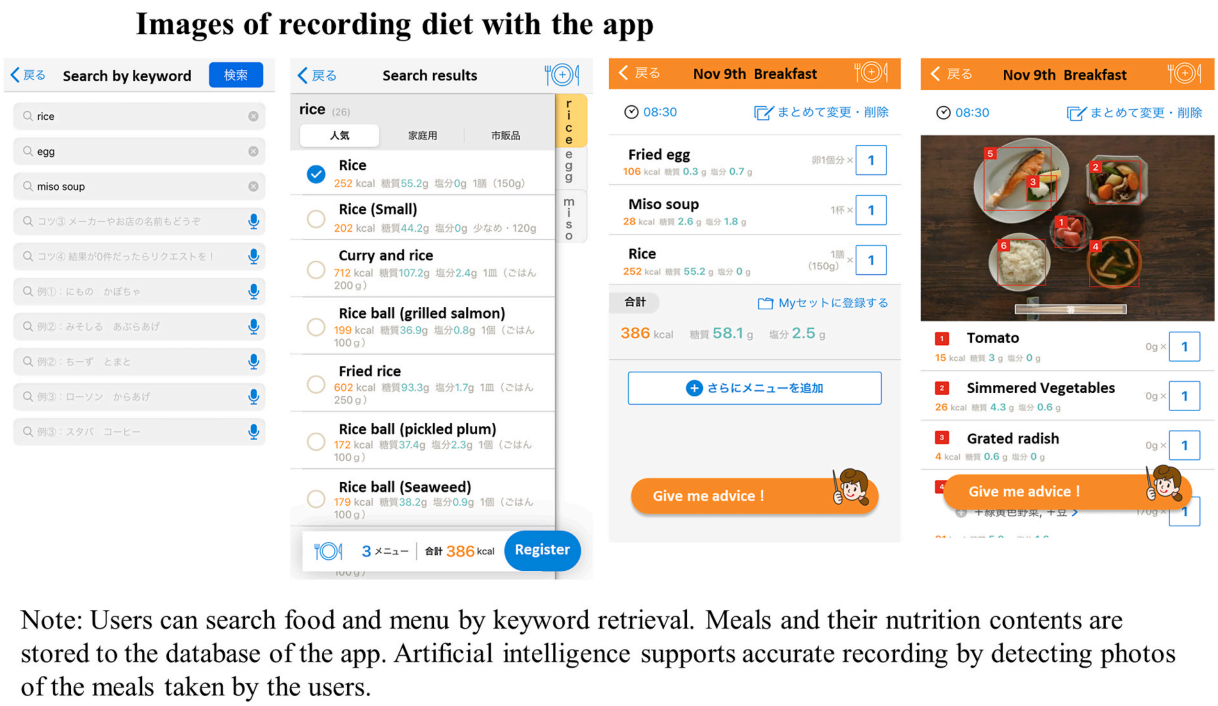

Fig. 2. Images of recording diet with the app.

Survey (equivalent to half piece of shiitake mushroom); seaweeds ≥5 g, corresponding to the mean intake of mushrooms per day (4.7 g) as per the National Health and Nutrition Survey (equivalent to Wakame seaweed in a cup of miso soup); fish ≥30 g, corresponding to the mean intake of fish per day (31.4 g) as per the National Health and Nutrition Survey (equivalent to two pieces of sashimi); meats ≥45 g, corresponding to the median intake of meats per day (47.4 g) as per the National Health and Nutrition Survey; dairy products ≥50 g, corresponding to the mean intake of dairy products per day (56.6 g) as per the National Health and Nutrition Survey and half of one serving of dairy products (100 g) as per the Japanese Food Guide; snacks >0 g of confectionaries, such as potato chips, cakes, and chocolates; alcohol ≥7.5 g (equivalent to 200 mL of beer). As indicated in Supplement Table B, we also examined a change in the frequency of intake of self-made meals defined as the number of recorded items not identified from restaurants or manufacturers.

2.3. Explanatory variables

Our data have a long-style structure, with two data lines per participant, one from the pre-declaration period and one from the declaration period. We were interested in changes in dietary patterns during the pandemic; thus, we constructed a dummy variable indicating zero if the data are from the pre-declaration period and one if from the declaration period. Through the online survey, we examined the participants' work and life patterns before and after the declaration by analyzing how they spent their average weekday before/after the spread of COVID-19. Participants categorized their average weekday according to time spent working away from home, working at home, commuting, taking care of children, doing housework, exercising, eating, sleeping, and other activities for the periods before and after the declaration. Some people worked both away from home and at home, and we defined a dummy variable for WFH to indicate those who spent more time working at home than away from home based on data from the self-reported questionnaire. Working hours were calculated as the total time spent working away from home and at home. We also adjusted for employment status at the time of survey (i.e., the declaration period) categorized as self-employed, manager, non-management worker, irregular worker, and non-worker. Probable depressive symptoms during the pandemic were also assessed using the Two-Question Screening (Spitzer et al., 1994), which comprised the following questions: (a) "During the past month, have you often been bothered by feeling down, depressed, or hopeless?" and (b) "During the past month, have you often been bothered by little interest or pleasure in doing things?" We defined individuals with probable depressive symptoms as those who answered "Yes" to either or both questions. The two-item instrument was validated (sensitivity: 91.8%, specificity: 67.7%, c-statistic: 0.90), and its performance was comparable with other screening tools (Tsoi et al., 2017). Information on participants' age and gender was also collected.

2.4. Statistical analysis

We used generalized linear mixed models to analyze the longitudinal data. Our data had two levels: time-variant variables (i.e., the frequencies of food intakes, a dummy of the declaration period and WFH, and hours of working, childcare, housework, eating, exercise, and sleep) at level 1 were nested within individuals at level 2; individual-level variables were age, gender, employment status, and depressive symptoms during the declaration period. A Poisson distribution was adopted to the count of intake of the food groups other than alcohol, while a negative binomial distribution was adopted to the count of drinking alcohol to handle overdispersion (i.e., the distribution consisted of many non-drinkers). To consider a variation in the number of days that the dietary data existed across participants, we included an offset term (i.e., a log of the number of days that dietary data exists) at level 1 in the models. All analyses were performed using Stata version 16.1 (StataCorp, College Station, TX).

3. Results

Table 1 describes the characteristics of participants. Most of the participants were non-management workers (34.0%), followed by non-workers, irregular workers, managers, and self-employed. During the declaration periods, the proportion of people who engaged in WFH rose from 5.6% to 27.8%; working hours decreased on average; time spent on other activities (i.e., childcare, housework, eating, exercise, and sleep)

Table 1
Characteristics of participants, 2020, Japan (N = 5929).

	Pre-declaration period [a]	Declaration period [a]	P-value [b]
Age (mean (SD))	44.0 (13.8)		
Gender (n (%))			
Men	1842 (31.1)		
Women	4087 (68.9)		
Employment status (n (%))			
Self-employed	327 (5.5)		
Manager	879 (14.8)		
Non-management worker	2014 (34.0)		
Irregular worker	1344 (22.7)		
Non-worker	1365 (23.0)		
Probable depressive symptoms (n (%))	2449 (41.3)		
Feeling down, depressed, or hopeless	1705 (28.8)		
Little interest or pleasure in doing things	1626 (27.4)		
Working from home (n (%))	332 (5.6)	1672 (28.2)	<0.001
Work and life patterns (hours (SD))			
Working hours	7.13 (3.72)	5.85 (4.05)	<0.001
Childcare	0.70 (1.84)	0.93 (2.32)	<0.001
Housework	1.86 (1.71)	2.28 (1.89)	<0.001
Eating	1.55 (0.76)	1.69 (0.80)	<0.001
Exercise	0.84 (0.88)	0.92 (0.85)	<0.001
Sleep	6.46 (1.15)	6.85 (1.31)	<0.001
The number of recorded items(per person-days, mean (SD))			
Vegetables	1.65 (1.02)	1.69 (1.08)	0.07
Fruits	0.52 (0.59)	0.52 (0.60)	0.89
Beans	0.77 (0.62)	0.80 (0.65)	0.054
Mushrooms	0.48 (0.42)	0.45 (0.44)	0.01
Seaweeds	0.37 (0.37)	0.38 (0.38)	0.47
Fish	0.40 (0.30)	0.38 (0.30)	0.02
Meats	0.94 (0.47)	0.92 (0.48)	0.03
Dairy products	0.67 (0.58)	0.70 (0.60)	0.002
Snacks	1.03 (0.90)	1.02 (0.91)	0.64
Alcohol	0.20 (0.39)	0.19 (0.40)	0.15

[a] We defined the period from January 1 to April 6 and from April 7 to May 13 as the "pre-declaration period" and the "declaration period," respectively. Out of 5929 participants, 212 had recorded dietary data during the pre-declaration period only and 1,281, during the declaration period only, while the remaining participants recorded data during both periods.

[b] P-values for t-tests comparing between the pre-declaration period and the declaration period.

increased. Among the participants, 41.3% presented with probable depressive symptoms.

Table 2 shows results from generalized linear mixed models. During the declaration period, the frequency of intake of vegetables (incidence rate ratio = 1.06, 95% confidence interval = 1.05–1.07), beans (1.05, 1.03–1.06), seaweeds (1.09, 1.06–1.11), fish (1.03, 1.01–1.05), meats (1.02, 1.01–1.04), dairy products (1.07, 1.05–1.09), and snacks (1.04, 1.03–1.06) increased, whereas that of alcohol decreased (0.94, 0.89–0.99). WFH was associated with increased intake of vegetables (1.02, 1.004–1.03), fruits (1.06, 1.03–1.09), dairy products (1.03, 1.01–1.06), and snacks (1.04, 1.02–1.06) but decreased intake of seaweeds (0.94, 0.91–0.97), meats (0.98, 0.96–0.999), and alcohol intake (0.93, 0.86–0.997). Working people tended to consume less fruits and dairy products but more meats and alcohol compared with non-workers. In particular, irregular workers consumed less vegetables (0.93, 0.89–0.97), mushrooms (0.94, 0.89–0.99), and fish (0.88, 0.84–0.94). Time spent on childcare (per hour) was associated with decreased intake of vegetables (0.99, 0.99–0.996) and fruits (0.98, 0.97–0.99) but increased intake of meats (1.01, 1.01–1.02). Probable depressive symptoms were negatively associated with the frequency of food intake other than snacks and alcohol. We also examined a change in the frequency of intake of self-made meals (Supplement Table B). The declaration period and WFH were positively associated with the intake of self-made meals, whereas employment other than self-employed, working hours, and time spent on childcare were negatively associated with it.

To capture more details by characteristics of participants, we conducted stratified analyses. In terms of gender, WFH was more clearly associated with increased intake of vegetables, fruits, and dairy products and decreased alcohol intake among women than men (Supplement Table C). In addition, among women, time spent on childcare was associated with reduced intakes of vegetables and fruits (Supplement Table C). When we stratified participants by the age of 45 years, WFH was positively associated with intake of vegetables, fruits, mushrooms, fish, and dairy products but was negatively associated with alcohol intake among younger participants (Supplement Table D). Similar to women, time spent on childcare was associated with reduced intakes of vegetables and fruits among younger participants (Supplement Table D). In stratified models by employment status, there were some unique changes in diet during the declaration period. In particular, fruit intake increased among managers; intake of meats and snacks increased among non-management workers and irregular workers; alcohol intake decreased among non-management workers; and fish intake increased among non-workers (Supplement Table E). WFH was associated with increased intake of seaweeds and fish, fruits and beans, and snacks among self-employed, non-management workers, and managers and irregular workers, respectively (Supplement Table E).

We conducted several sensitivity analyses to check the robustness of our findings. First, to consider seasonality, we developed a seasonal index using data from the year 2019 and adjusted the estimation. In the data from 2019, the frequencies of food intake decreased in the period from April 7 to May 13 compared to the period from January 1 to April 6 for most of the food groups other than fish; thus, the seasonal index was below 1 (Supplement Table F). Therefore, the estimated coefficients of the declaration period were inflated in most food groups but changes to null in the models for fish and alcohol after adjusting for seasonality (Supplement Table G). Second, the number of new COVID-19 cases was increasing in the last weeks before the declaration, and work and life patterns may have been shifting in March. Hence, we excluded data from March (Supplement Table H). After excluding data from March, the coefficients of the declaration period showed negative associations with fruits and mushrooms intake, while its associations with fish and meats became vague. Regarding the WFH variable, we obtained similar results even after the data exclusion. Third, considering regional heterogeneity of infection spread, we added a dummy variable indicating participants who lived in eight prefectures where the declaration was lifted after May 14, 2020 (Supplement Table I). The eight prefectures are located in Tokyo and Osaka metropolitan areas and Hokkaido. Out of 5929 participants, 4580 provided their information on the prefecture of residence. The dummy variable was associated with the intake of mushrooms, dairy products, and alcohol; however, the coefficients of other variables did not change very much after adjusting for the dummy of eight prefectures.

4. Discussion

This study explored how the COVID-19 pandemic and work and life patterns were associated with dietary changes using longitudinal data from the users of *CALO mama* health app. We found that the frequency of intake of vegetables, beans, seaweeds, fish, meats, dairy products, and snacks increased, whereas alcohol intake decreased during the declaration period. WFH was associated with increased intake of vegetables, fruits, dairy products, and snacks but decreased intake of seaweeds, meats, and alcohol intake. Overall, we estimated that those who started WFH during the declaration period increased intake of vegetables by 8%, dairy products by 11%, and snacks by 8%, and decreased alcohol intake by 13% in terms of frequency. These changes in dietary patterns were similar to those observed in previous reports from Spain, Italy, Brazil, Colombia, and Chile (Rodríguez-Pérez et al., 2020; Ruiz-Roso et al., 2020; Scarmozzino & Visioli, 2020). Nevertheless, time spent on childcare was associated with decreased intake of vegetables and fruits

Table 2
Generalized linear mixed models for the frequency of food intake, 2020, Japan[a].

	Vegetables			Fruits			Beans			Mushrooms			Seaweeds		
	IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI	
Declaration period	1.06	1.05	1.07	1.01	0.99	1.03	1.05	1.03	1.06	1.02	0.999	1.04	1.09	1.06	1.11
Working from home	1.02	1.004	1.03	1.06	1.03	1.09	1.01	0.99	1.03	1.02	0.99	1.05	0.94	0.91	0.97
Employment status [b]															
Self-employed	0.97	0.90	1.04	0.82	0.70	0.97	1.07	0.97	1.18	1.08	0.99	1.19	1.01	0.90	1.13
Manager	0.97	0.92	1.03	0.73	0.65	0.83	0.98	0.91	1.05	1.01	0.95	1.09	1.05	0.96	1.14
Non-management worker	0.96	0.91	0.997	0.67	0.61	0.74	0.95	0.90	1.01	0.99	0.94	1.05	0.99	0.92	1.06
Irregular worker	0.93	0.89	0.97	0.70	0.63	0.77	0.94	0.89	1.005	0.94	0.89	0.99	0.97	0.90	1.04
Working hours	1.00	0.996	1.002	1.00	0.99	1.005	1.00	0.997	1.005	1.00	0.995	1.004	1.00	0.999	1.01
Childcare	0.99	0.99	0.996	0.98	0.97	0.99	1.00	0.99	1.005	1.00	0.99	1.01	1.00	0.996	1.01
Housework	1.00	0.99	1.01	1.00	0.99	1.01	1.02	1.01	1.03	1.01	1.003	1.02	1.00	0.99	1.01
Eating	1.03	1.02	1.04	1.03	1.01	1.05	1.01	0.99	1.03	1.01	0.99	1.03	1.02	0.997	1.04
Exercise	1.01	1.001	1.02	1.02	1.01	1.04	1.03	1.02	1.04	1.02	1.01	1.03	1.02	1.001	1.03
Sleep	1.00	0.99	1.01	1.02	1.004	1.03	1.00	0.99	1.01	0.99	0.98	1.01	1.00	0.99	1.01
Depressive symptoms	0.92	0.90	0.95	0.89	0.83	0.95	0.95	0.91	0.99	0.93	0.90	0.97	0.93	0.89	0.97
Women	1.06	1.02	1.10	1.60	1.47	1.75	0.98	0.94	1.03	1.13	1.08	1.18	0.82	0.77	0.86
Age	1.003	1.002	1.004	1.01	1.01	1.01	0.999	0.997	1.001	1.00	0.998	1.001	1.004	1.002	1.01
Offset	2.94	2.91	2.97	2.95	2.89	3.01	2.86	2.82	2.90	3.06	3.01	3.12	2.96	2.90	3.02
Constant	0.96	0.87	1.06	0.11	0.09	0.13	0.51	0.45	0.59	0.25	0.21	0.28	0.19	0.16	0.23

	Fish			Meats			Dairy products			Snacks			Alcohol		
	IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI	
Declaration period	1.03	1.01	1.05	1.02	1.01	1.04	1.07	1.05	1.09	1.04	1.03	1.06	0.94	0.89	0.99
Working from home	0.99	0.96	1.02	0.98	0.96	0.999	1.03	1.01	1.06	1.04	1.02	1.06	0.93	0.86	0.997
Employment status [b]															
Self-employed	0.99	0.91	1.08	1.04	0.98	1.10	0.83	0.73	0.94	0.95	0.85	1.06	2.48	1.75	3.52
Manager	1.01	0.94	1.08	1.12	1.07	1.17	0.79	0.72	0.87	0.92	0.84	0.997	5.08	3.87	6.66
Non-management worker	0.96	0.90	1.01	1.10	1.06	1.15	0.89	0.82	0.96	1.00	0.94	1.07	3.17	2.52	3.97
Irregular worker	0.88	0.84	0.94	1.06	1.02	1.10	0.89	0.83	0.97	1.01	0.94	1.08	1.69	1.34	2.14
Working hours	1.00	0.998	1.007	1.00	0.998	1.004	1.00	0.997	1.005	0.99	0.99	0.997	0.99	0.97	1.001
Childcare	1.00	0.997	1.01	1.01	1.01	1.02	1.00	0.99	1.004	1.00	0.996	1.01	1.00	0.97	1.03
Housework	1.00	0.99	1.01	1.00	0.996	1.01	1.00	0.99	1.01	0.99	0.98	0.995	1.01	0.97	1.04
Eating	1.03	1.01	1.05	1.01	1.001	1.03	1.02	1.005	1.04	0.99	0.98	1.01	1.20	1.13	1.27
Exercise	1.01	0.999	1.03	1.00	0.99	1.01	1.03	1.02	1.04	1.01	0.996	1.02	0.98	0.95	1.02
Sleep	1.01	0.998	1.02	1.00	0.99	1.003	1.01	0.996	1.02	0.98	0.97	0.99	1.00	0.96	1.03
Depressive symptoms	0.96	0.92	0.99	0.96	0.94	0.99	0.92	0.87	0.97	0.99	0.95	1.04	0.97	0.83	1.12
Women	0.92	0.88	0.97	0.83	0.80	0.85	1.16	1.09	1.24	1.83	1.73	1.94	0.32	0.27	0.38
Age	1.005	1.004	1.01	0.99	0.99	0.99	1.003	1.001	1.005	0.996	0.99	0.998	1.03	1.02	1.04
Offset	2.99	2.93	3.06	2.93	2.89	2.97	2.86	2.81	2.91	2.91	2.87	2.96	2.93	2.78	3.08
Constant	0.18	0.16	0.21	0.98	0.89	1.08	0.32	0.27	0.38	0.56	0.49	0.65	0.00	0.00	0.01

abrAbbreviationsIRR, incidence rate ratio; CI, confidence interval.
[a] A Poisson distribution was adopted to the frequency of food intake other than alcohol, while a negative binomial distribution was adopted to the frequency of alcohol intake.
[b] A reference category is "non-worker."

but increased intake of meats. Probable depressive symptoms were negatively associated with the frequency of food intakes other than snacks and alcohol.

We noted that diet quality improved in general, given the increased vegetable intake during the declaration period. Previous studies demonstrated that vegetable consumption raises the intake of various nutrients and can represent overall diet quality (Aljadani et al., 2013; Hoy et al., 2019; Su & Arab, 2006; Wakita Asano et al., 2008). Increasing vegetable intake is a promising strategy to ensure adherence to dietary recommendations (Sebastian et al., 2019). Increased intake of vegetables and fruits is associated with a reduced risk of cardiovascular disease, cancer, all-cause mortality (Aune et al., 2017), and stroke (He et al., 2006). The effects of dairy and alcohol intake on health outcomes are still controversial, but a negative association between dairy intake and risk of type 2 diabetes (Schwingshackl et al., 2017) and a positive association between alcohol intake and risk of cancer (GBD 2016 Alcohol Collaborators, 2018; Scoccianti et al., 2016) have been observed. The dietary pattern changes observed in this study can be attributed to a change in eating location. Previous studies have shown that eating outside of home is associated with higher intake of energy and fat, lower intake of fiber and micronutrients (e.g., vitamin C, Ca, and Fe), and obesity (Bezerra et al., 2012; Goffe et al., 2017; Lachat et al., 2012; Myhre et al., 2014; Nago et al., 2014). It is likely that the stay-at-home measure during the pandemic kept people away from consuming unhealthy foods outside of home and encouraged them to prepare self-made meals instead.

We also demonstrated for the first time association between WFH and dietary patterns. WFH reduces the consumption of food outside of home but increases the chances of consuming self-made meals. In addition, WFH benefits people by eliminating commute time. Lack of time to prepare healthy meals has been considered the main barrier to healthy eating (Escoto et al., 2012; Munt et al., 2017; Welch et al., 2009). WFH could mitigate this time constraint and allow people to prepare healthier meals. Our stratified analyses showed that women, young, and non-management workers, in particular, benefited from WFH through healthy meals such as vegetables, fruits, and beans. These groups may have been overwhelmed with their work in the office and commuting, but WFH may have enabled them to manage their time at home.

However, the declaration period and WFH were associated with an increased frequency of snacking. The pandemic is a stressful event, and stress can increase the intake of palatable foods as an adaptation to it (Sinha & Jastreboff, 2013). Indeed, a positive association between consuming snacks and stress has been observed (Oliver & Wardle, 1999). People who were new to WFH during the declaration period may especially be prone to stress due to an unfamiliar way of working.

Particularly, we observed increased snacking among non-management workers and irregular workers during the declaration period. These groups may be subjected to more changes in work and life patterns during the pandemic, which is likely to induce more snacking.

Increased time spent on childcare was associated with decreased frequencies of intake of vegetables and fruits and increased frequencies of intake of meats. During the pandemic, most nurseries and schools were closed, and 47.1% of mothers and 29.3% of fathers reported that the time spent on childcare increased by > 5 h per day in Japan (The Center for Early Childhood Development, Education, and Policy Research, 2020). Our findings showed that a 5-h increase in time spent on childcare corresponded to 4% and 8% reductions in the frequency of intake of vegetables and fruits, respectively. In our stratified analyses, time spent on childcare was more clearly associated with reductions in vegetable and fruit intake among women and young participants than other groups. These groups are considered to have a particularly heavy burden of childcare and may have lacked time to consume healthy foods.

This study has several limitations. First, it may lack generalizability because participants were users of a health app, and the distribution of participants was skewed as the majority of participants were female participants in their 40s. To overcome this limitation in the future, a population-based study may be useful. Second, we could not adjust for some covariates such as education, household income, number of children, marital status, and whether participants usually cook by themselves. If these factors were confounding, the estimations could be biased. Third, although the app recorded the amount of intake of nutrients and ingredients based on a pre-defined standard menu, we decided to analyze the frequency of food intake instead of their amounts because the recording method using the app has not been validated. However, studies have pointed out that frequency is a more important factor in measuring food intake than portion size (Molag et al., 2007; Pérez Rodrigo et al., 2015). It has also been shown that the length of a food list in a food frequency questionnaire improves the ability to measure food intake (Molag et al., 2007). In this regard, we had the advantage as the app had a list of 150,000 foods. Moreover, we compared the intake of nutrients and foods among our participants with the national average (Supplement Table J). Our participants appeared to take more dietary fiber, vitamin A and C, and calcium, and less sugars, fruits, and fish than the average, but they were not very different in other nutrients and foods. Further validation studies will allow researchers to provide in-depth information on dietary patterns recorded by health apps.

Despite these limitations, the strength of our study is its longitudinal data, which enabled us to measure dietary changes before and after the pandemic without recall bias. The use of health apps can promote "precision nutrition," which is defined by the National Institutes of Health as a holistic approach to developing comprehensive and dynamic nutritional recommendations with a wide array of considerations, including genetics, dietary habits and eating patterns, circadian rhythms, health status, socioeconomic and psychosocial characteristics, food environments, physical activity, and the microbiome (Rodgers & Collins, 2020; US Department of Health & Human Services; National Institutes of Health, 2020). Health apps embedding image analysis and artificial intelligence can overcome the limitations of self-reporting diet questionnaires and provide information on diet patterns in real-time. Big data allows researchers to study the effect of dietary intake on health and diseases more accurately and provide tailored recommendations to individuals and evidence-based guidelines for the population.

In conclusion, we explored dietary changes during the COVID-19 pandemic using data from health app users and note that the quality of diet improved in general because the declaration period and WFH were associated with increased frequencies of intake of vegetables and other nutritious foods. These findings suggest that people, in particular, non-management and irregular workers, should avoid excessive intake of snacks while staying at home. Increased time spent on childcare and probable depressive symptoms were inversely associated with vegetable and fruit intake, and attention must be paid to people who are subject to these negative factors for healthy eating during the pandemic.

Author contributions

Conceptualization, KS and SK; Methodology, Software, and Formal Analysis, KS; Investigation, KS, MY, RS, YS, CM, and NK; Data Curation, RS; Writing – Original Draft, KS; Writing – Review & editing, KS, SK, MY, RS, YS, CM, and NK; Visualization, KS and RS; Supervision, NK; Funding Acquisition, KS and NK.

Ethical statement

This study was approved by the Research Ethics Committee of the Graduate School of Medicine/Faculty of Medicine, the University of Tokyo (2019372NI-(1)).

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Data availability

Data are available upon reasonable request to Link & Communication Inc.

Declaration of competing interest

SK, RS, YS, and CM were employees of Link & Communication Inc. that provides the app *CALO mama*.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2021.105323.

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