# Loneliness and social isolation factors under the prolonged COVID-19 pandemic in Japan: A two-year longitudinal study

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## *Abstract*

**Background:** Worsening loneliness and social isolation during the coronavirus disease 2019 (COVID-19) pandemic have become serious public health concerns worldwide. despite previous research reporting persistent loneliness and social isolation under repeated emergency declarations and prolonged pandemic, long-term studies are needed to identify the actual conditions of loneliness and social isolation, and the factors that explain them.

**Objective:** In this study, three online surveys were conducted at one-year intervals during the two years after the first state of emergency to examine changes in loneliness and social isolation and the psychosocial factors associated with them, in the Japanese population.

**Methods:** The first survey period (Phase 1, May 11-12, 2020) was conducted at the end of the first emergency declaration period, the second survey (Phase 2, June 15-20, 2021) was conducted at the end of the third emergency declaration period, and the third survey (Phase 3, May 13-30, 2022) was conducted when the state of emergency had not been declared but many COVID-19 positive cases occurred during this period. We collected data on 3892 inhabitants (1813 women, 50.3±13.4 years old) living in the four prefectures where emergency declaration measures were applied in phases 1 and 2. A linear mixed model analysis was performed to examine the association between psychosocial variables as explanatory variables and loneliness scores as the dependent variable in each phase.

**Results:** While many psychosocial and physical variables showed improvement for the two years, loneliness, social isolation, and the relationship with familiar people deteriorated, and the opportunities for exercise, favorite activities, and online interaction with familiar people decreased. Nearly half of social isolation in phase 1 remained throughout the two-year period, and a greater number of people developed social isolation than those who were able to resolve it. The results of the linear mixed model analysis showed that most psychosocial and physical variables were related to loneliness regardless of the phase. Regarding the variables that showed a significant interaction with the phase, increased altruistic preventive behavior and a negative outlook for the future were more strongly associated with severe loneliness in phase 3, while association between fewer social networks and stronger loneliness tended to be more pronounced in phase 2. Although the interaction was not significant, the association between less face-to-face interaction, worse relationships with familiar people, and worse loneliness tended to be stronger in phase 3.

**Conclusions:** This study showed that the problems of loneliness and social isolation have remained unresolved during the long-term COVID-19 pandemic, and a variety of factors are more strongly related to loneliness and are more complex in the last survey phase than in earlier phases.

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Original Paper

# Loneliness and social isolation factors under the prolonged COVID-19 pandemic in Japan: A two-year longitudinal study

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## Abstract

**Background:** Worsening loneliness and social isolation during the coronavirus disease 2019 (COVID-19) pandemic have become serious public health concerns worldwide. despite previous research reporting persistent loneliness and social isolation under repeated emergency declarations and prolonged pandemic, long-term studies are needed to identify the actual conditions of loneliness and social isolation, and the factors that explain them.
**Objective:** In this study, three online surveys were conducted at one-year intervals during the two years after the first state of emergency to examine changes in loneliness and social isolation and the psychosocial factors associated with them, in the Japanese population.
**Methods:** The first survey period (Phase 1, May 11-12, 2020) was conducted at the end of the first emergency declaration period, the second survey (Phase 2, June 14-20, 2021) was conducted at the end of the third emergency declaration period, and the third survey (Phase 3, May 13-30, 2022) was conducted when the state of emergency had not been declared but many COVID-19 positive cases occurred during this period. We collected data on 3892 inhabitants (1813 women, 50.3±13.4 years old) living in the four prefectures where emergency declaration measures were applied in phases 1 and 2. A linear mixed model analysis was performed to examine the association between psychosocial variables as explanatory variables and loneliness scores as the dependent variable in each phase.
**Results:** While many psychosocial and physical variables showed improvement for the two years, loneliness, social isolation, and the relationship with familiar people deteriorated, and the opportunities for exercise, favorite activities, and online interaction with familiar people decreased. Nearly half of social isolation in phase 1 remained throughout the two-year period, and a greater number of people developed social isolation than those who were able to resolve it. The results of the linear mixed model analysis showed that most psychosocial and physical variables were related to loneliness regardless of the phase. Regarding the variables that showed a significant interaction with the phase, increased altruistic preventive behavior and a negative outlook for the future were more strongly associated with severe loneliness in phase 3, while association between fewer social networks and stronger loneliness tended to be more pronounced in phase 2. Although the interaction was not significant, the association between less face-to-face interaction, worse relationships with familiar people, and worse loneliness tended to be stronger in phase 3.
**Conclusions:** This study showed that the problems of loneliness and social isolation have remained unresolved during the long-term COVID-19 pandemic, and a variety of factors are more strongly related to loneliness and are more complex in the last survey phase than in earlier phases.

**Keywords:** coronavirus disease 2019; pandemic; loneliness; social isolation; longitudinal survey; epidemiology; mental health

## Introduction

Since its outbreak in December 2019, coronavirus disease 2019 (COVID-19) has spread rapidly worldwide [1]. To deter its spread, many countries imposed repeated lockdowns, such as restricting people's movement and temporarily closing services. However, while lockdowns were effective at preventing the spread of infection, they caused significant financial hardship and psychological distress [2, 3].

The lockdown and stay-at-home orders announced globally during the COVID-19 pandemic have led to physical and social distancing, and many individuals have experienced social isolation [1, 4]. Increased loneliness during the stay-at-home period is strongly associated with severe depression and suicidal ideation [5, 6]. However, the magnitude of social support during the pandemic was inversely associated with suicidal ideation and self-harm [7]. Thus, worsening loneliness and social isolation during the COVID-19 pandemic has become a serious public health concern.

In Japan, four states of emergency owing to the COVID-19 pandemic were declared between 2020 and 2021. While many countries were in lockdown with penalties for violations, a unique feature of Japan's COVID-19 policy was that the government requested that people refrain from going out except in an emergency, certain businesses closed temporarily, and no penalties were imposed for violations. Since the declaration of a state of emergency in Japan was a "request" by the government, it did not prohibit going out or meeting people. However, as in other countries, Japan's mild lockdown [8] affected people's lives in many ways, including lifestyle changes due to teleworking and online classes, and economic hardships due to reduced income and unemployment. Our previous research reported severe loneliness, social isolation, and psychological distress during the state of emergency in Japan [4, 9].

Several longitudinal studies have reported persistent problems of loneliness and social isolation during repeated emergency declarations and prolonged pandemics in Japan. In our longitudinal studies conducted during the pandemic (May 2020 and February 2021), whereby a state of emergency was declared. in the Japanese population [10], there were no improvements in severe social isolation and loneliness between the two phases, although psychological distress significantly improved, and depression slightly decreased. Another longitudinal survey conducted during the latter half of the second wave and at the end of the fifth wave of the pandemic in Japan reported that from the first to the second year of the COVID-19 pandemic, social isolation (the evaluation method was different from the one we used) decreased but loneliness increased [11]. This study was not conducted under emergency conditions. The loneliness of the Japanese people was severe not only during the period when the state of emergency was declared but also during other periods when the COVID-19 infection spread.

Unlike other psychological variables mentioned above, loneliness and social isolation during a pandemic are unlikely to improve through longitudinal observation. Therefore, a long-term study is needed to identify the actual conditions of loneliness and social isolation, and the factors that explain them. In this study, three surveys were conducted at one-year intervals during the two years after the first state of emergency, to examine changes in loneliness and social isolation and the psychosocial factors associated with them. The first survey (phase 1, May 11-12, 2020) was conducted at the end of the first emergency declaration period, the second survey (phase 2, June 15-20, 2021) was conducted at the end of the third emergency declaration period, and the third survey (phase 3, May 13-30, 2022) was conducted when the state of emergency was not declared but many COVID-19 positive cases occurred during this period (Figure 1). This study will enable us to observe changes in loneliness and social isolation across long-term periods as well as changes in these variables with changes in social conditions, such as the declaration of a state of emergency, thereby providing useful

information for considering when and which factors to intervene in during a prolonged pandemic.

## Methods

### Participants and Data Collection

Online surveys were conducted between May 11 and 12, 2020 (phase 1); June 14 and 20, 2021 (phase 2); and May 13 and 30, 2022 (phase 3). The first and third states of emergency were declared in phases 1 and 2, respectively. In phase 1, we conducted an online survey of inhabitants living in seven prefectures where emergency measures were first applied (Tokyo, Kanagawa, Osaka, Saitama, Chiba, Hyogo, and Fukuoka) to precisely detect the impact of the declaration. We recruited participants according to the following inclusion criteria: (a) inhabitants living in the seven prefectures mentioned above and (b) age ≥18 years. The exclusion criteria were as follows: (a) aged < 18 years, (b) high school students, and (c) living outside the seven prefectures. In phase 1, 11,333 individuals participated and the number of people in each prefecture was determined based on the ratio of the number of people living in Tokyo (n=2783, 24.6%), Kanagawa (n=1863, 16.4%), Osaka (n=1794; 15.8%), Saitama (n=1484; 13.1%), Chiba (n=1263; 11.1%), Hyogo (n=1119; 9.9%), and Fukuoka (n=1027; 9.1%). We conducted a follow-up survey on the same participants in phase 2 but excluded inhabitants living in Kanagawa, Saitama, and Chiba, where the emergency declaration was not applied from the survey in phase 2. In Phase 2, we collected data from 4592 individuals who lived in Tokyo, Osaka, Hyogo, and Fukuoka and had participated in survey Phase 1. In Phase 3, 3892 participants who participated in Phases 1 and 2 responded to an additional follow-up survey.

Study participants were recruited through Macromill Inc. (Tokyo, Japan), a global marketing research company. This company has access to more than 1,300,000 registered members, with diverse characteristics regarding sex and age, from all prefectures in Japan. The online survey system automatically eliminated duplicate answers from a single respondent. Approximately 80,000 registered people living in the target areas were recruited via email, and data were collected on an online platform. Participants completed the online survey after receiving a link. All participants voluntarily and anonymously responded to the survey and provided informed consent online before completing the survey. The participants received a clear explanation of the survey procedure and could discontinue or terminate the survey at any time without providing a reason. The questionnaire format, excluding the default items provided by Macromill Inc. (sex, age, occupation, annual household income, marital status, and presence of children), did not allow participants to proceed to the next page if there were items they had not answered. All participants received Macromill points for their participation, which constituted an original point service of Macromill, Inc., and participants could exchange these points for prizes or cash.

This study was approved by the Research Ethics Committee of the Graduate School of Social and Industrial Science and Technology at Tokushima University (approval no. 212). This study was conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and its subsequent amendments.

The data in the phase for this study were partly extracted from a database containing the data used in our previous studies [12, 13]. The extracted data were secondarily reanalyzed with dependent and independent variables different from those in the studies mentioned above. A detailed explanation of the dataset used in this study is provided by Sugaya et al. [14].

### Measures

### Sociodemographic Data

Sociodemographic information was collected on participants, including age, sex, employment status (employed, homemaker, student, unemployed, or other), marital status, and annual household income (<2.0 million JPY, 2.0–3.9 million JPY, 4.0–5.9 million JPY, 6.0–7.9 million JPY, ≥ 8.0 million JPY, or unknown). Additionally, Phases 2 and 3 included number of cohabitants.

### Loneliness

Loneliness was measured using the Japanese version of the UCLA Loneliness Scale Version 3 (UCLA-LS3) [15]. The UCLA-LS3 consists of 10 items rated from 1 (never) to 4 (always) [16]. Total scores ranged from 10 to 40, with higher scores indicating higher levels of loneliness.

### Social Isolation

We measured social networks using the Japanese version of the abbreviated Lubben Social Network Scale (LSNS-6) [17]. The LSNS-6 is a shortened version of the Lubben Social Network Scale [18] which includes items on the network size of relatives or friends who provide emotional and instrumental support. The LSNS-6 consists of three items related to family networks and three related to friendship networks. The number of people in the network was calculated using a 6-point scale (0=none; 1=one; 2=two, 3=three or four; 4=five–eight; 5=nine or more) for each item [19]. The total score ranges from 0 to 30 points, with higher scores indicating a larger social network and scores of <12 points indicating social isolation.

Loneliness and social isolation are conceptually distinct, with social isolation generally defined in terms of the objective availability of social contacts and the frequency of contact with social network members. Loneliness refers to the perception that personal and social needs are not being met [20, 21]. Moreover, social isolation is reportedly related to loneliness and is often a risk factor [22].

### Psychological Distress

We used the Japanese version of the Kessler Psychological Distress Scale-6 (K6) [23], a non-specific psychological stress scale. The K6 is a 6-item screening instrument that measures distress over the past 30 days. Each question is rated on a scale of 0 (never) to 4 (always), with total scores ranging from 0 to 24. The K6 is considered an ideal instrument for screening mental disorders in population-based health surveys because of its brevity and high accuracy [23-25].

### Depressive symptoms

We used the Japanese version of the Patient Health Questionnaire-9 (PHQ-9) [26] to collect basic information on participants' mental health; the PHQ-9 consists of nine questions. Participants reported depressive symptoms during the past four weeks with a score of 0 (none) to 3 (nearly every day) [27].

### Physical symptoms

The Japanese version of the Somatic Symptom Scale-8 (SSS-8) was used to assess physical symptom burden [28]. The SSS-8 consists of eight items that assess the following somatic symptoms: stomach or bowel problems; back pain; pain in the arms, legs, or joints; headaches; chest pain or shortness of breath; dizziness; feeling tired or having low energy; and trouble sleeping. These items comprise four symptom domains: gastrointestinal, pain, cardiopulmonary, and fatigue. Participants reported how much each symptom had bothered them during the previous 7 days, with a score of 0 to 4 (0 = not at all; 1 = a little bit; 2 =

somewhat; 3 = quite a bit; 4 = very much) [29].

### *Lifestyle, Coping Behavior, and Stressors Related to COVID-19 pandemic*

With extensive references to the literature on the COVID-19 pandemic [30-34], we developed eight lifestyle and coping behavior items, and seven stressors were assumed to be associated with the COVID-19 pandemic (Refer to Sugaya et al, 2020; Yamamoto et al, 2020, Appendix 1) [8, 12]. We asked participants to rate the frequency of implementation and their experience of these items from the start of the state of emergency (phases 1 and 2) or the last 30 days (phase 3) to the time of the survey, on a scale of 1 (not at all) to 7 (extremely). The item details are described in our previously published articles [8, 12].

## Statistical analysis

Analysis of variance (ANOVA) was applied to compare the psychosomatic variables and items of the COVID-19 pandemic, between the phases. The chi-square test was used to compare sociodemographic data between the social isolation groups (participants were assigned to each group based on their LSNS-6 scores). Repeated 2-way ANOVA was conducted to confirm the interactions between demographic characteristics and phases on the UCLA-LS3 score. We applied a linear mixed model to effectively analyze the diverse variables and data from the three time points. To select variables for the linear mixed model, multiple regression analysis using the stepwise method was performed with the UCLA-LS3 score as the dependent variable and the other variables as explanatory variables in each phase. Variables significantly associated with the UCLA-LS3 score in the multiple regression analysis were used as explanatory variables in the linear mixed-model analysis, which was conducted to examine the association between these explanatory variables and the UCLA-LS3 score as the dependent variable in each phase, with the participants as random effect. For all tests, significance was set at $\alpha$ = .05, 2-tailed. Statistical analyses were performed using SPSS Statistics version 29.0 (IBM Corp., NY, USA).

# Results

## Descriptive Results

Table 1 shows the sociodemographic characteristics of the participants. A total of 3892 individuals participated in phases 1, 2, and 3 (1813 [46.6%] women, mean age 50.3 years [SD 13.4], range 18-89 years in phase 1). Thus, 2831 (42.1%) of the 6723 individuals who lived in Tokyo, Osaka, Hyogo, and Fukuoka and who participated in Phase 1 did not respond in Phases 2 or 3. In addition, there were significantly more females than males among individuals who did not participate in phases 2 or 3. Individuals who did not participate in phase 2 or 3 were younger and had lower UCLA-LS3 scores and higher LSNS-6, K6, PHQ-9, and SSS-8 scores than those who participated in the three phases.

In the comparisons of psychosocial and physical variables between phases, there were significant differences between phases in all variables except “Healthy sleep habits.” Regarding the UCLA-LS3, “Healthy eating habits,” “Altruistic preventive behavior,” “Deterioration of household economy,” “Frustration,” and “COVID-19-related sleeplessness,” results did not exceed the lower limit of “small effect size” ($\eta^2 \geq 0.010$). While many indicators showed improvement from phase 1 to phase 3, there were increases in the UCLA-LS3 scores and “Deterioration of relationship with familiar people,” and decreases in the LSNS-6 scores, “Exercise,” “Favorite activity,” and “Online interaction with familiar people.”

### Transition of the presence of social isolation during three phases

Figure 2 shows the transitions in the presence of social isolation during the three phases. Of the 2316 individuals who were socially isolated in phase 1, 360 (15.5%) were no longer socially isolated in phase 2, whereas 473 (30.0%) of the 1576 individuals who were not socially isolated in phase 1 became socially isolated in phase 2. Of the 2429 persons who were socially isolated in phase 2, 373 (15.4%) were no longer socially isolated in phase 3, whereas 413 (28.2%) of the 1463 persons who were not socially isolated in phase 2 became socially isolated in phase 3. In addition, 45.7% of the total respondents were consistently socially isolated in all three phases.

### Social isolation and psychosocial and physical variables in three phases

Table 2 shows the number of individuals experiencing social isolation based on sociodemographic characteristics between the three phases. Regarding the sex differences, more men than women were socially isolated in all phases (phase 1: $\chi^2 = 24.66$, $p < 0.001$; phase 2: $\chi^2 = 18.31$, $p < 0.001$; phase 3: $\chi^2 = 21.96$, $p < 0.001$). In all phases, fewer people were socially isolated in the 65 and older group and more in the 50-64 age group; in phase 1 and phase 3, fewer people were socially isolated in the 18-29 age group (phase 1: $\chi^2 = 33.94$, $p < 0.001$; phase 2: $\chi^2 = 32.64$, $p < 0.001$; phase 3: $\chi^2 = 46.17$, $p < 0.001$). Regarding occupation, in all phases, fewer homemakers were socially isolated and greater number of people were unemployed; in phases 1 and 2, there were more socially isolated individuals in the other occupation group than in either occupation groups ($\chi^2 = 28.24$, $p < 0.001$; phase 2: $\chi^2 = 37.08$, $p < 0.001$; phase 3: $\chi^2 = 38.76$, $p < 0.001$). A greater number of unmarried individuals were socially isolated than married individuals in all three phases (phase 1: $\chi^2 = 100.11$, $p < 0.001$; phase 2: $\chi^2 = 117.89$, $p < 0.001$; phase 3: $\chi^2 = 97.75$, $p < 0.001$). In every phase, individuals without children were more likely to be socially isolated ($\chi^2 = 119.57$, $p < 0.001$; phase 2: $\chi^2 = 161.92$, $p < 0.001$; phase 3: $\chi^2 = 147.96$, $p < 0.001$). Regarding annual household, in all phases, there were more socially isolated people in the under JPY 2.0 million group and JPY 2.0-3.9 million group, and fewer in the over JPY 8.0 million group (phase 1: $\chi^2 = 111.73$, $p < 0.001$; phase 2: $\chi^2 = 92.98$, $p < 0.001$; phase 3: $\chi^2 = 106.68$, $p < 0.001$).

Table 3 compares the psychosocial and physical variables between participants with and without social isolation in each phase. In phase 1, there were significant differences between participants with and without social isolation in psychosocial and physical variables, except for COVID-19-related anxiety, sleeplessness, and difficulties in work or schoolwork. In phase 2, there were significant differences between participants with and without social isolation in psychosocial and physical variables, except for COVID-19-related anxiety and sleeplessness, difficulties due to the lack of daily necessities, and difficulties in work or schoolwork. In phase 3, there were significant differences between participants with and without social isolation in all psychosocial and physical variables.

### Comparison of loneliness between phases and between socio-demographic characteristics

Table 4 shows interactions between phases and socio-demographic characteristics, and the main effects of each independent variable in the UCLA-LS3 score. There was a significant interaction between phases and sex in the UCLA-LS3 score. In all phases, the UCLA-LS3 scores in male participants were significantly higher than the scores in females (phase 1 and 3: $p < 0.001$; phase 2: $p = 0.022$); for both males and females ($p < 0.001$ in all phases), the UCLA-LS3 scores in phase 2 (male: $p = 0.047$; female: $p < 0.001$) and phase 3 (male: $p = 0.032$; female: $p < 0.001$) were significantly higher than the score in phase 1. The main effect of group and time were significant for all demographic characteristics (main effect of phase for occupation: $p = 0.002$; other analyses: $p < 0.001$). Regarding age groups, the group for over 65 years old had

lower UCLA scores than all other age groups ($p < 0.001$), and the group of 50 to 64 years old had lower scores than the group of 30 to 49 years old group ($p < 0.001$). For occupation, the employed group had lower UCLA-LS3 scores than the other group that did not fit into any of the four categories ($p = 0.029$), and the homemaker group had lower scores than other occupation groups except students($p < 0.001$). The unmarried group had higher UCLA-LS3 scores than the married group. Participants without children showed higher score than those with children. Regarding annual household income, group under JPY 2.0 million had higher UCLA-LS3 scores than other household income groups ($p < 0.001$) and groups with more than JPY 8.0 million showed lower scores than JPY 2.0 to 3.9 million ($p < 0.001$), 4.0 to 5.9 million ($p = 0.002$), and 6.0 to 7.9 million groups ($p = 0.038$).

### Psychosocial and physical factors associated with loneliness in the three phases

Table 5 shows the results of the linear mixed model analysis of the psychosocial and physical factors associated with loneliness in the three phases. Multiple regression analyses were performed for each phase, and explanatory variables significantly associated with UCLA-LS3 scores were applied in a linear mixed model. Sex ($F = 56.95$, $p < 0.001$), marital status ($F = 36.45$, $p < 0.001$), age ($F = 57.10$, $p < 0.001$), K6 ($F = 76.37$, $p < 0.001$), PHQ-9 ($F = 109.29$, $p < 0.001$), SSS-8 ($F = 9.17$, $p = 0.002$), LSNS-6 ($F = 1173.01$, $p < 0.001$), exercise ($F = 14.06$, $p < 0.001$), offline ($F = 82.46$, $p < 0.001$) and online ($F = 60.46$, $p < 0.001$) interaction with familiar people, optimism ($F = 147.41$, $p < 0.001$), deterioration of household economy ($F = 28.80$, $p < 0.001$), deterioration of relationship with familiar people ($F = 80.30$, $p < 0.001$), and frustration ($F = 54.36$, $p < 0.001$) had significant effect on the UCLA-LS3 scores. Marital status ($F = 3.17$, $p = 0.042$), LSNS-6 ($F = 3.53$, $p = 0.029$), altruistic preventive behavior ($F = 10.87$, $p < 0.001$), optimism ($F = 3.06$, $p = 0.047$), and deterioration of household economy ($F = 3.76$, $p = 0.023$) showed significant interactions with phases. Regarding marital status, the unmarried group had significantly higher scores on the UCLA-LS3 in all phases and showed a significant increase in the scores between phases 1 and 2. The married group showed a significant increase in the score between all phases. The altruistic preventive behavior scores in phases 1 and 2 were more negatively related to the UCLA-LS3 score than in phase 3. The optimism scores in phase 3 were more negatively related to the UCLA-LS3 scores than phases 1 and 2 scores. The LSNS-6 scores and deterioration of the household economy did not show a significant difference in the relationship with the UCLA-LS3 between the phases.

## Discussion

### Change of loneliness and social isolation for two years

While many psychosocial and physical variables showed improvement for two years, loneliness, social isolation, and the relationship with familiar people deteriorated, and the opportunities for exercise, favorite activities, and online interaction with familiar people decreased. Both loneliness and social isolation were severe compared to the results of studies conducted prior to the COVID-19 pandemic. In previous studies conducted during the non-pandemic period in Japan, the mean score of UCLA-LS3 was 17.5 points and that of the LSNS-6 was 16.2 points [15, 17]. The deterioration or lack of improvement over the past two years is a serious problem. Our results were consistent with previous studies in other countries to some extent; a systematic review showed that loneliness did not significantly improve during the pandemic [35], and a German study [36] reported that depression increased from the pre-pandemic to the first wave (June 2020), but declined in the second pandemic wave; loneliness increased during the first and second waves of the pandemic (January and February 2021). While people adapted to the repeated declarations of the state of emergency and the wave of

increasing COVID-19 infections, there may have been an increased number of cases, exacerbating relationship problems. Future research comparing this region with areas that were not in a declared state of emergency could clarify this impact.

### The relationship between social isolation and psychosocial and physical variables

Nearly half of the individuals experiencing social isolation in phase 1 remained socially isolated throughout the two-year period. In addition, the presence or absence of social isolation over the two-year period shifted to some extent within individuals, and more people developed social isolation than those who were able to resolve it. Thus, many people were unable to escape long-term social isolation during the pandemic, and in many cases, the scarcity of social networks became more severe over a long period. The results indicate that the problem of social isolation during the pandemic must be identified and addressed from a long-term perspective.

There were no notable differences in the association between social isolation and demographic characteristics between the phases, and significantly more men, people in the 50-64 age group, unemployed, unmarried, childless, and those with a household income below 3.9 million yen were socially isolated in all phases. Regarding the association between psychosocial and physical variables, in addition to worsening general physical and mental indicators such as loneliness, psychological distress, depression, and physical symptoms, they also had problems with lifestyle (exercise, diet, and sleep), frustration, deteriorated interpersonal relationships, decreased social interaction (both online and offline), decreased favorite activities, and a negative outlook for the future. They also exhibited fewer preventive behaviors to avoid infecting others, which may be an effect of fewer opportunities for interaction. The effect size was very small, except in phase 3, although it was significant for higher household financial deterioration. Anxiety and sleep problems related to COVID-19, lack of daily necessities, and difficulties in work and study, which were not significantly different between the groups in phases 1 and 2, were significantly different between the groups in phase 3; however, the effect size was very small. These results indicate that during the two years of the pandemic (whether under a declared state of emergency or not), the factors associated with a severe and persistent lack of social networks did not change significantly, indicating the need to strengthen isolation measures, especially for specific genders, age groups, income groups, and family structures, and to assess and improve physical and mental status, lifestyle habits, and social network interventions.

### The relationship between loneliness and psychosocial and physical variable

In all phases, loneliness was significantly higher among males, the 50-64 age group, the childless group, and the group with annual household incomes less than JPY 2 million; this is similar to the results of social isolation. In terms of occupation, loneliness was high in the "other" group, which did not fit into any occupation category, but this result was difficult to interpret because the kind of employment status was unclear.

The results of the linear mixed model analysis showed that most psychosocial and physical variables were related to loneliness regardless of the phase. Regarding the variables that showed a significant interaction with the phases, increased altruistic preventive behavior and a negative outlook for the future were more strongly associated with severe loneliness in phase 3. Among the variables that had significant interactions with the phases, the LSNS-6 score showed no significant differences in association by phase; however, the association between fewer social networks and stronger loneliness tended to be more pronounced in phase 2. In addition, although the interaction was not significant, the association between fewer face-to-face interactions, worse relationships with familiar people, and worse loneliness tended to be

stronger in phase 3. The factors that increase loneliness during a pandemic may become more varied and complex over time. Figure 3 indicates movement trends in Japan during the COVID-19 pandemic by geography across different categories of places such as retail and recreation, groceries and pharmacies, parks, transit stations, workplaces, and residential areas (Google LLC) [37]. This figure shows that phase 1 was a period of significant decrease in travel to retail/ recreation, transit stations, and workplaces, and this phenomenon normalized from phases 2 and 3. Under a declared state of emergency for COVID-19 (i.e., the first half of the survey period), the environmental changes caused by following social demands led to social isolation, and loneliness was intensified. However, even if the life changes associated with the social situation later eased, interpersonal interactions and relationships did not improve, and the lack of positive thinking due to prolonged pandemic may have exacerbated loneliness and social isolation. Regarding altruistic preventive behavior, another longitudinal survey [38] reported that an increase in physical isolation was only present for people with high COVID-19 concern during the pandemic, in contrast to the early part of the pandemic in Japan, when many people refrained from going out. The latter part of the survey period was a time when people's behavior was changing toward normalization, and those who were cautious about infection may have increased their sense of isolation by missing parties and other activities with their peers.

As this study and other previous studies have shown, the problems of loneliness and social isolation have remained unresolved during the long-term COVID-19 pandemic; therefore, they should be urgently addressed to protect people's mental health. A systematic review of interventions to reduce social isolation and loneliness during the COVID-19 physical distancing measures [39] indicated that the most effective interventions for loneliness involved either cognitive or educational components or facilitated communication and networking between peers. Although there were few effective interventions for social isolation, it was stated that remote intervention could be effective. By establishing a system that provides online interventions that can effectively and directly relieve loneliness while simultaneously improving the factors associated with loneliness that have changed over time since the start of the pandemic and with varying social conditions, as identified in this study, we can prepare for the social isolation and loneliness that could occur in future pandemics. In particular, this study showed that a variety of factors were more strongly related to loneliness and were more complex in the last survey phase than in the earlier phases, suggesting that preventive interventions may be important in the early stages of a pandemic to efficiently improve loneliness and social isolation. Online interventions may be particularly useful in the early stages of a pandemic, when the virus is not well characterized and people are strongly urged to refrain from going out.

## Limitation

This study has several limitations. First, as the data were collected through an online survey, random sampling was not conducted. Therefore, we cannot guarantee the representativeness of the sample, as it cannot be matched to the percentages of each age group or sex in each region. In addition, people registered with online survey companies may be more willing to participate in surveys than those who are not. They may have social networks through which they can obtain information on such cooperation. The population not registered with the survey firm may have more severely socially isolated individuals who may have different characteristics and require additional support. Regarding family environment, for example, the 2020 Census reported that 58.6% of the Japanese population aged 20 and older were married [40]. While 64.0% of the participants in this study were married, which is comparatively high, the small number of elderly participants who were bereaved of spouses

suggests that this was not a particularly large proportion of married people. From this perspective, the living environments of the registrants of the survey company, who formed the study population, may not have been significantly different, in relation to social isolation or loneliness, from those of the non-registrant population. However, most previous studies conducted in Japan during the COVID-19 pandemic using the LSNS-6 and the UCLA were conducted on survey company registrants, and it is difficult to rigorously compare these results with a non-registered population. It is necessary to interpret these results by considering the possibility that experiences of isolation and loneliness may differ between registrants and non-registrants. Second, significant differences between individuals who participated in the three phases and those who did not participate in phases 2 or 3 were indicated for some sociodemographic characteristics and psychological variables.

## Conclusion

The results of this study indicate that the problems of loneliness and social isolation remain unresolved during the long-term COVID-19 pandemic. While nearly half of the social isolation in the early phase of the pandemic persisted throughout the two-year period, more people developed social isolation than those who were able to resolve it. Demographic characteristics (male sex, the 50-64 age-group, lower income, etc.) and psychosocial variables (psychological distress, lifestyle, relationship, and interaction with familiar people), which were related to social isolation, were consistent for the two years. Additionally, factors that increased loneliness during the pandemic became more varied and complex over time. By establishing a system that provides interventions that can effectively relieve loneliness by considering the factors associated with loneliness that have changed over time since the start of the pandemic and with varying social conditions, we may be better able to prepare for the social isolation and loneliness that could occur in future pandemics.

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N Sugaya, TY, CU, and N Suzuki conceived, designed, and performed the study; contributed to and wrote the paper; and approved the final manuscript. N Sugaya analyzed the data.

## Conflicts of Interest

None declared.

## Abbreviations

COVID-19: coronavirus disease 2019
UCLA-LS3: University of California, Los Angeles (UCLA) Loneliness Scale, Version 3
LSNS-6: Lubben Social Network Scale (shortened version)
K6: Kessler Psychological Distress Scale-6
PHQ-9: Patient Health Questionnaire-9

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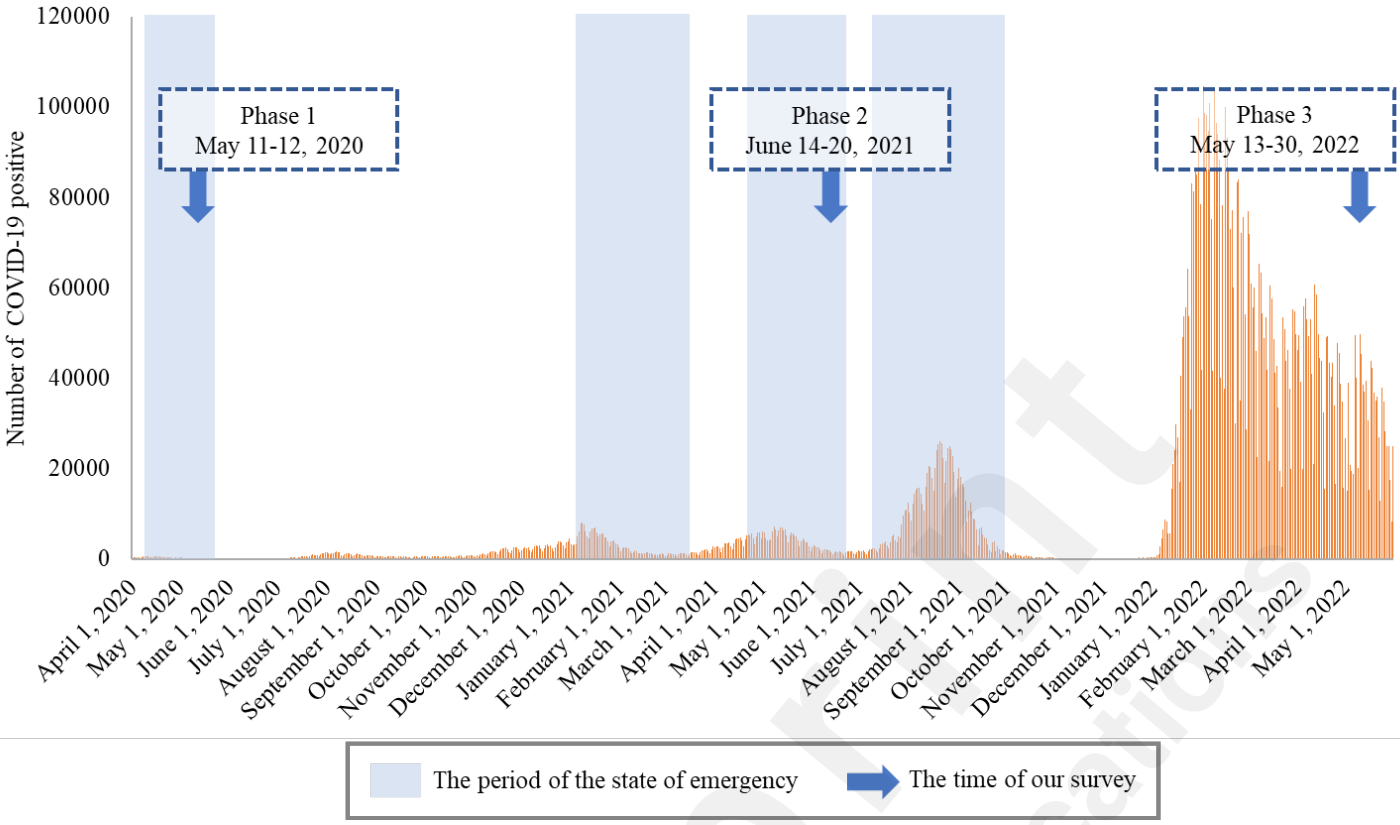
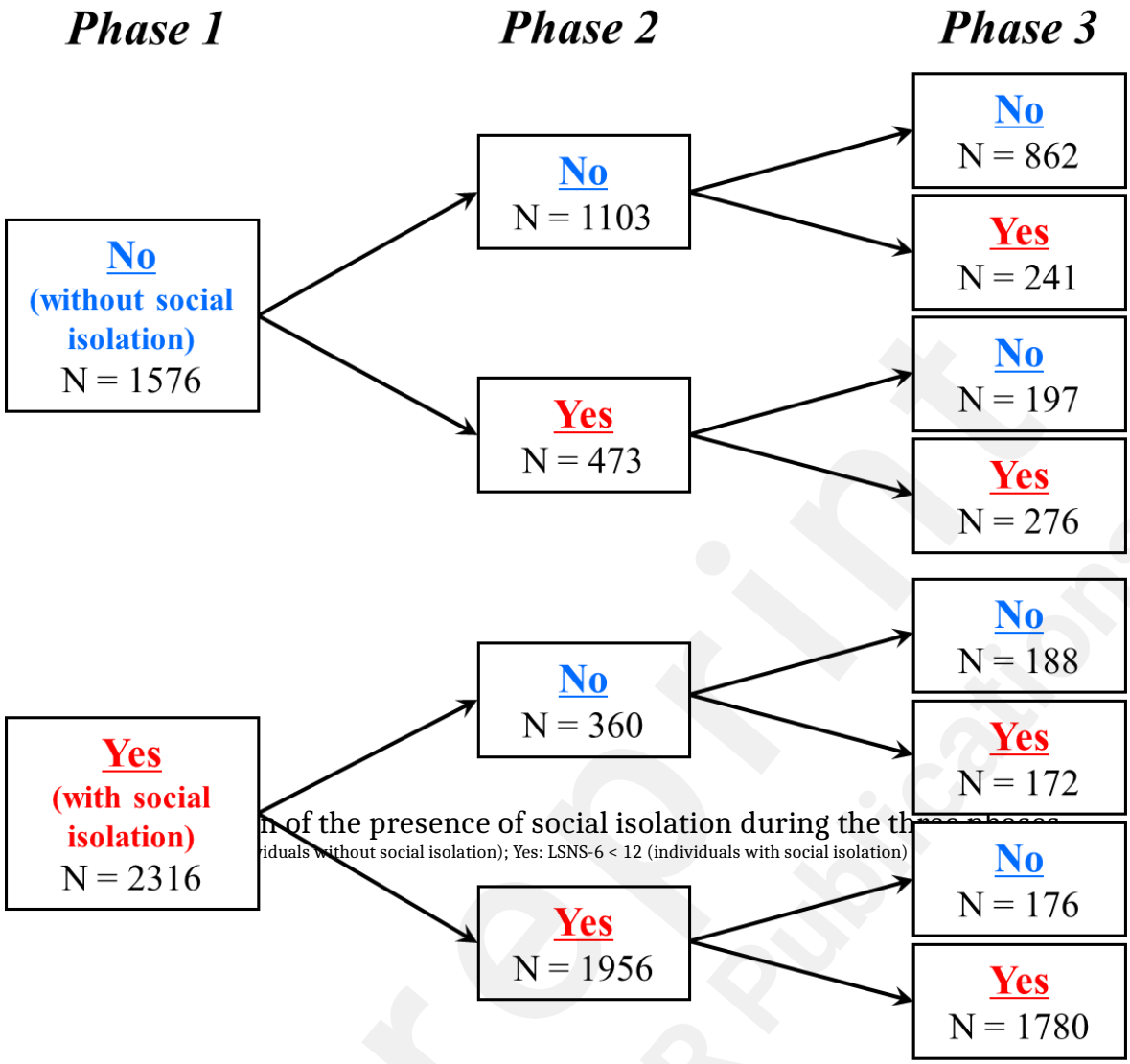
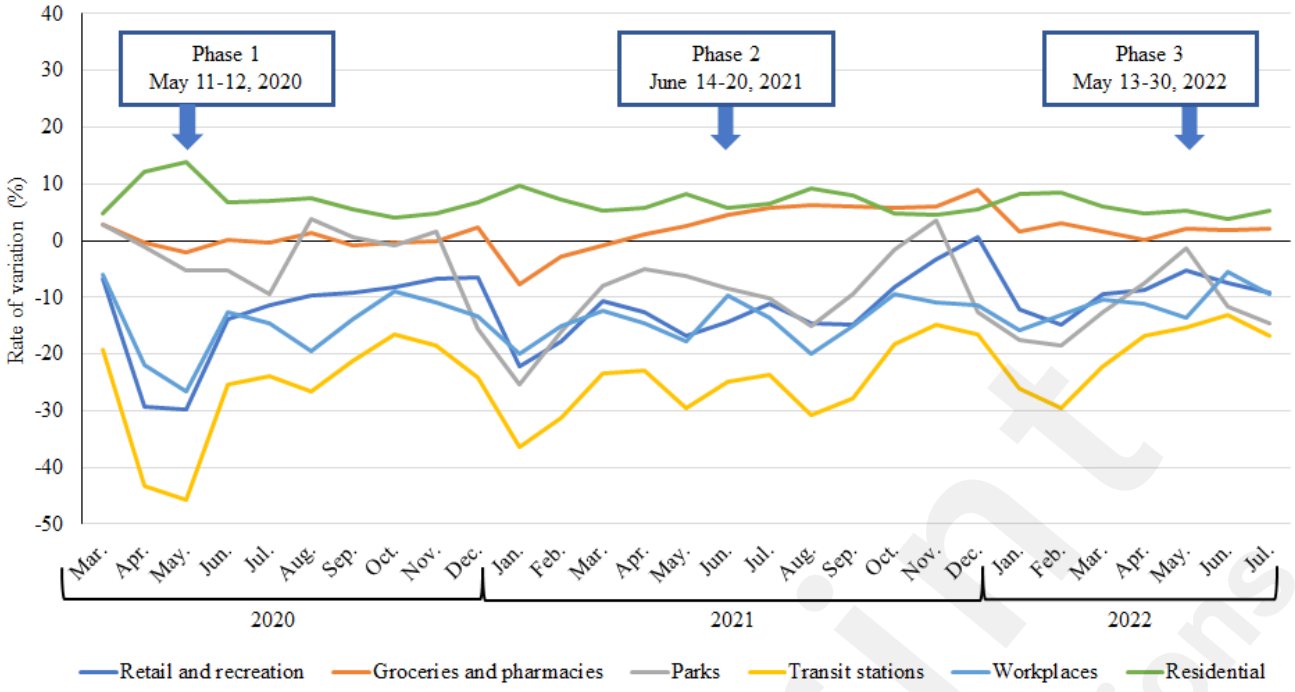





n of the presence of social isolation during the th

iduals without social isolation); Yes: LSNS-6 < 12 (individuals with social isolation)

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3 – Feb 6,

Table 1. Change in psychosocial and physical variables during three phases

| | Phase 1 | | Phase 2 | | Phase 3 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | (SD) | Mean | (SD) | Mean | (SD) | $F$ | $p$ | $\eta^2$ |
| UCLA-LS3 | 23.6 | (5.8) | 24.0 | (5.9) | 23.9 | (6.0) | 21.48 | <0.001 | 0.005 |
| LSNS-6 | 10.0 | (6.1) | 9.4 | (6.0) | 9.3 | (6.0) | 42.94 | <0.001 | 0.011 |
| K6 | 5.1 | (5.3) | 4.0 | (5.2) | 3.9 | (5.4) | 167.66 | <0.001 | 0.041 |
| PHQ-9 | 4.4 | (5.4) | 3.9 | (5.4) | 3.8 | (5.4) | 44.05 | <0.001 | 0.011 |
| SSS-8 | 6.3 | (5.5) | 5.1 | (5.5) | 5.1 | (5.5) | 187.41 | <0.001 | 0.046 |
| Exercise | 4.1 | (1.8) | 3.8 | (1.9) | 3.8 | (1.9) | 95.75 | <0.001 | 0.024 |
| Healthy eating habits | 4.3 | (1.5) | 4.2 | (1.6) | 4.2 | (1.6) | 19.89 | <0.001 | 0.005 |
| Healthy sleep habits | 4.7 | (1.7) | 4.7 | (1.7) | 4.8 | (1.7) | 2.21 | 0.111 | 0.001 |
| Favorite activity | 4.0 | (1.6) | 3.7 | (1.7) | 3.8 | (1.7) | 53.23 | <0.001 | 0.013 |
| Offline interaction with familiar people | 3.5 | (1.8) | 3.3 | (1.8) | 3.9 | (1.8) | 177.67 | <0.001 | 0.044 |
| Online interaction with familiar people | 3.1 | (1.9) | 2.7 | (1.7) | 2.8 | (1.8) | 90.16 | <0.001 | 0.023 |
| Altruistic preventive behavior | 5.4 | (1.7) | 5.4 | (1.7) | 5.4 | (1.7) | 3.89 | 0.021 | 0.001 |
| Optimism | 4.0 | (1.5) | 4.2 | (1.5) | 4.3 | (1.5) | 69.17 | <0.001 | 0.017 |
| Deterioration of household economy | 3.7 | (1.8) | 3.5 | (1.7) | 3.5 | (1.7) | 35.68 | <0.001 | 0.009 |
| Deterioration of relationship with familiar people | 2.4 | (1.5) | 2.6 | (1.6) | 2.6 | (1.5) | 61.53 | <0.001 | 0.016 |
| Frustration | 3.2 | (1.7) | 3.2 | (1.7) | 3.1 | (1.7) | 4.43 | 0.035 | 0.001 |
| COVID-19-related anxiety | 3.9 | (1.7) | 3.4 | (1.7) | 3.2 | (1.6) | 324.70 | <0.001 | 0.077 |
| COVID-19-related sleeplessness | 2.5 | (1.5) | 2.5 | (1.5) | 2.4 | (1.5) | 5.58 | 0.004 | 0.001 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Difficulties owing to the lack of daily necessities | 3.5 (1.8) | 2.5 (1.5) | 2.5 (1.5) | 684.09 | <0.001 | 0.150 |
| Difficulties in work or schoolwork | 3.6 (2.0) | 2.8 (1.7) | 2.7 (1.7) | 465.29 | <0.001 | 0.107 |

Table 2. Social isolation and sociodemographic characteristics in each phase

| Socio-demographic indexes | N (%) at Phase 1 | | | N (%) at Phase 2 | | | N (%) at Phase 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | With social isolation | Without social isolation | Total | With social isolation | Without social isolation | Total | With social isolation | Without social isolation |
| Overall | 3892 | 2316 (59.5%) | 1576 (40.5%) | 3892 | 2429 (62.4%) | 1463 (37.6%) | 3892 | 2469 (63.4%) | 1423 (36.6%) |
| **Sex** | | | | | | | | | |
| *Males* | 2079 | 1313 (63.2%) | 766 (36.8%) | 2079 | 1362 (65.5%) | 717 (34.5%) | 2079 | 1387 (66.7%) | 692 (33.3%) |
| *Females* | 1813 | 1003 (55.3%) | 810 (44.7%) | 1813 | 1067 (58.9%) | 746 (41.1%) | 1813 | 1082 (59.7%) | 731 (40.3%) |
| **Age** | | | | | | | | | |
| *18-29* | 273 | 134 (49.1%) | 139 (50.9%) | 224 | 132 (58.9%) | 92 (41.1%) | 186 | 102 (54.8%) | 84 (45.2%) |
| *30-49* | 1575 | 954 (60.6%) | 621 (39.4%) | 1514 | 966 (63.8%) | 548 (36.2%) | 1448 | 921 (63.6%) | 527 (36.4%) |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *50-64* | 1395 | 885 | (63.4%) | 510 | (36.6%) | 1454 | 956 | (65.7%) | 498 | (34.3%) | 1510 | 1035 | (68.5%) | 475 | (31.5%) |
| *≥65* | 649 | 343 | (52.9%) | 306 | (47.1%) | 700 | 375 | (53.6%) | 325 | (46.4%) | 748 | 411 | (54.9%) | 337 | (45.1%) |
| **Occupation** | | | | | | | | | | | | | | | |
| *Employed* | 2693 | 1607 | (59.7%) | 1086 | (40.3%) | 2677 | 1682 | (62.8%) | 995 | (37.2%) | 2693 | 1728 | (64.2%) | 965 | (35.8%) |
| *Homemaker* | 585 | 308 | (52.6%) | 277 | (47.4%) | 594 | 321 | (54.0%) | 273 | (46.0%) | 566 | 301 | (53.2%) | 265 | (46.8%) |
| *Student* | 46 | 21 | (45.7%) | 25 | (54.3%) | 27 | 12 | (44.4%) | 15 | (55.6%) | 19 | 10 | (52.6%) | 9 | (47.4%) |
| *Unemployed* | 443 | 294 | (66.4%) | 149 | (33.6%) | 480 | 328 | (68.3%) | 152 | (31.7%) | 564 | 395 | (70.0%) | 169 | (30.0%) |
| *Other* | 125 | 86 | (68.8%) | 39 | (31.2%) | 114 | 86 | (75.4%) | 28 | (24.6%) | 50 | 35 | (70.0%) | 15 | (30.0%) |
| **Marital status** | | | | | | | | | | | | | | | |
| *Married* | 2489 | 1334 | (53.6%) | 1155 | (46.4%) | 2500 | 1403 | (56.1%) | 1097 | (43.9%) | 2490 | 1437 | (57.7%) | 1053 | (42.3%) |
| *Unmarried* | 1403 | 982 | (70.0%) | 421 | (30.0%) | 1392 | 1026 | (73.7%) | 366 | (26.3%) | 1402 | 1032 | (73.6%) | 370 | (26.4%) |
| **The presence of child** | | | | | | | | | | | | | | | |
| *Yes* | 2175 | 1128 | (51.9%) | 1047 | (48.1% | 2226 | 1199 | (53.9%) | 1027 | (46.1% | 2224 | 1230 | (55.3%) | 994 | (44.7%) |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ) | | | | ) | | | | | |
| *No* | 1717 | 1188 | (69.2%) | 529 | (30.8%) | 1666 | 1230 | (73.8%) | 436 | (26.2%) | 1668 | 1239 | (74.3%) | 429 | (25.7%) |
| **The number of cohabitants** | | | | | | | | | | | | | | | |
| *0* | - | - | | - | | 467 | 353 | (75.6%) | 114 | (24.4%) | 635 | 488 | (76.9%) | 147 | (23.1%) |
| *1* | - | - | | - | | 1212 | 829 | (68.4%) | 383 | (31.6%) | 1156 | 775 | (67.0%) | 381 | (33.0%) |
| *2* | - | - | | - | | 1003 | 628 | (62.6%) | 375 | (37.4%) | 949 | 609 | (64.2%) | 340 | (35.8%) |
| *3* | - | - | | - | | 753 | 405 | (53.8%) | 348 | (46.2%) | 742 | 409 | (55.1%) | 333 | (44.9%) |
| *4* | - | - | | - | | 332 | 160 | (48.2%) | 172 | (51.8%) | 303 | 143 | (47.2%) | 160 | (52.8%) |
| *>= 5* | - | - | | - | | 125 | 54 | (43.2%) | 71 | (56.8%) | 107 | 45 | (42.1%) | 62 | (57.9%) |
| **Annual household income (JPY)** | | | | | | | | | | | | | | | |
| *< 2.0 million* | 223 | 183 | (82.1%) | 40 | (17.9%) | 247 | 195 | (78.9%) | 52 | (21.1%) | 333 | 262 | (78.7%) | 71 | (21.3%) |
| *2.0-3.9 million* | 737 | 498 | (67.6%) | 239 | (32.4%) | 765 | 544 | (71.1%) | 221 | (28.9%) | 756 | 539 | (71.3%) | 217 | (28.7%) |
| *4.0-5.9* | 775 | 461 | (59.5%) | 314 | (40.5% | 802 | 479 | (59.7%) | 323 | (40.3% | 754 | 478 | (63.4%) | 276 | (36.6%) |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *million* | | | | ) | | | | ) | | | | | | |
| *6.0-7.9 million* | 525 | 305 | (58.1%) | 220 | (41.9%) | 515 | 317 | (61.6%) | 198 | (38.4%) | 517 | 309 | (59.8%) | 208 | (40.2%) |
| *>= 8.0 million* | 819 | 394 | (48.1%) | 425 | (51.9%) | 821 | 428 | (52.1%) | 393 | (47.9%) | 846 | 437 | (51.7%) | 409 | (48.3%) |

Table 3. Comparison of psychosocial and physical variables between participants with and without social isolation in each phase

| | Phase 1 | | | | | Phase 2 | | | | | Phase 3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | With social isolation | Without social isolation | *t* | *p* | *Cohen's d* | With social isolation | Without social isolation | *t* | *p* | *Cohen's d* | With social isolation | Without social isolation | *t* | *p* | *Cohen's d* |
| UCLA-LS3 | 25.83 (5.25) | 20.29 (4.82) | 33.43 | <0.001 | 1.092 | 26.13 (5.43) | 20.42 (4.89) | 32.97 | <0.001 | 1.091 | 25.98 (5.46) | 20.33 (4.98) | 32.07 | <0.001 | 1.068 |
| K6 | 5.79 (5.64) | 4.16 (4.52) | 10.02 | <0.001 | 0.314 | 4.56 (5.60) | 2.92 (4.32) | 10.28 | <0.001 | 0.319 | 4.66 (5.79) | 2.58 (4.21) | 12.89 | <0.001 | 0.395 |
| PHQ-9 | 5.22 (5.83) | 3.30 (4.36) | 11.74 | <0.001 | 0.363 | 4.55 (5.93) | 2.84 (4.34) | 10.36 | <0.001 | 0.318 | 4.57 (5.88) | 2.43 (4.14) | 13.23 | <0.001 | 0.402 |
| SSS-8 | 6.74 (5.82) | 5.63 (4.93) | 6.43 | <0.001 | 0.203 | 5.59 (5.79) | 4.36 (4.95) | 7.05 | <0.001 | 0.225 | 5.66 (5.82) | 4.05 (4.65) | 9.47 | <0.001 | 0.297 |
| Exercise | 3.81 (1.83) | 4.61 (1.64) | 14.32 | <0.001 | 0.458 | 3.47 (1.88) | 4.21 (1.81) | 12.07 | <0.001 | 0.396 | 3.58 (1.87) | 4.30 (1.83) | 11.73 | <0.001 | 0.388 |
| Healthy eating habits | 4.03 (1.58) | 4.76 (1.37) | 15.39 | <0.001 | 0.489 | 3.93 (1.62) | 4.61 (1.46) | 13.53 | <0.001 | 0.436 | 3.97 (1.65) | 4.66 (1.49) | 13.36 | <0.001 | 0.433 |
| Healthy sleep habits | 4.50 (1.80) | 5.03 (1.61) | 9.54 | <0.001 | 0.305 | 4.50 (1.75) | 5.1 (1.55) | 11.05 | <0.001 | 0.355 | 4.57 (1.69) | 5.12 (1.53) | 10.48 | <0.001 | 0.339 |
| Favorite activity | 3.68 (1.67) | 4.39 (1.50) | 13.83 | <0.001 | 0.442 | 3.45 (1.70) | 4.08 (1.59) | 11.76 | <0.001 | 0.383 | 3.61 (1.70) | 4.24 (1.61) | 11.51 | <0.001 | 0.377 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Offline interaction with familiar people | 3.16 | (1.76) | 4.02 | (1.78) | 14.83 | <0.001 | 0.485 | 3.01 | (1.74) | 3.81 | (1.73) | 13.81 | <0.001 | 0.457 | 3.53 | (1.76) | 4.63 | (1.57) | 20.19 | <0.001 | 0.651 |
| Online interaction with familiar people | 2.63 | (1.75) | 3.75 | (1.95) | 18.38 | <0.001 | 0.612 | 2.39 | (1.62) | 3.09 | (1.84) | 12.01 | <0.001 | 0.410 | 2.52 | (1.68) | 3.28 | (1.89) | 12.48 | <0.001 | 0.429 |
| Altruistic preventive behavior | 5.18 | (1.85) | 5.79 | (1.41) | 11.55 | <0.001 | 0.359 | 5.22 | (1.79) | 5.74 | (1.47) | 9.84 | <0.001 | 0.310 | 5.21 | (1.76) | 5.59 | (1.53) | 7.03 | <0.001 | 0.225 |
| Optimism | 3.59 | (1.55) | 4.54 | (1.35) | 20.21 | <0.001 | 0.643 | 3.85 | (1.54) | 4.68 | (1.40) | 16.82 | <0.001 | 0.557 | 3.97 | (1.51) | 4.80 | (1.41) | 17.03 | <0.001 | 0.567 |
| Deterioration of household economy | 3.74 | (1.76) | 3.61 | (1.75) | 2.41 | 0.016 | 0.079 | 3.50 | (1.72) | 3.36 | (1.69) | 2.59 | 0.010 | 0.086 | 3.66 | (1.67) | 3.30 | (1.63) | 6.69 | <0.001 | 0.221 |
| Deterioration of relationship with familiar people | 2.52 | (1.54) | 2.16 | (1.42) | 7.53 | <0.001 | 0.242 | 2.68 | (1.56) | 2.53 | (1.57) | 2.91 | 0.004 | 0.096 | 2.79 | (1.56) | 2.39 | (1.48) | 7.96 | <0.001 | 0.261 |
| Frustration | 3.27 | (1.73) | 3.02 | (1.67) | 4.43 | <0.001 | 0.145 | 3.21 | (1.73) | 3.07 | (1.71) | 2.46 | 0.014 | 0.081 | 3.25 | (1.66) | 2.82 | (1.61) | 8.05 | <0.001 | 0.268 |
| COVID-19- | 3.93 | (1.7 | 3.96 | (1.67 | 0.53 | 0.593 | 0.01 | 3.44 | (1.69 | 3.43 | (1.64 | 0.23 | 0.817 | 0.00 | 3.28 | (1.61 | 3.17 | (1.6 | 2.04 | 0.042 | 0.068 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| related anxiety | 0) | | ) | | 7 | | ) | | ) | | 8 | | ) | | 1) | |
| COVID-19-related sleeplessness | 2.50 | (1.53) | 2.40 | (1.52) | 1.95 | 0.052 | 0.064 | 2.48 | (1.52) | 2.42 | (1.50) | 1.12 | 0.262 | 0.037 | 2.44 | (1.46) | 2.30 | (1.45) | 2.91 | 0.004 | 0.097 |
| Difficulties owing to the lack of daily necessities | 3.53 | (1.81) | 3.40 | (1.78) | 2.24 | 0.025 | 0.073 | 2.53 | (1.54) | 2.52 | (1.55) | 0.38 | 0.705 | 0.013 | 2.52 | (1.51) | 2.35 | (1.49) | 3.54 | <0.001 | 0.117 |
| Difficulties in work or schoolwork | 3.53 | (1.93) | 3.60 | (1.98) | 1.17 | 0.242 | 0.038 | 2.78 | (1.68) | 2.78 | (1.70) | 0.07 | 0.943 | 0.002 | 2.75 | (1.66) | 2.50 | (1.63) | 4.55 | <0.001 | 0.151 |

UCLA-LS3, UCLA Loneliness Scale (version 3); K6, Kessler Psychological Distress Scale-6; PHQ-9, Patient Health Questionnaire-9; SSS-8: Somatic Symptom Scale-8

Table 4. Comparison of loneliness between phases and between socio-demographic characteristics

| Socio-demographic indexes | Phase 1 | Phase 2 | Phase 3 | Interaction | | | Group | | | Phase | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean (SD) | Mean (SD) | Mean (SD) | *F* | *p* | $\eta_p^2$ | *F* | *p* | $\eta_p^2$ | *F* | *p* | $\eta_p^2$ |
| **Sex** | | | | 4.80 | 0.008 | 0.001 | 13.73 | <0.001 | 0.004 | 22.71 | <0.001 | 0.006 |
| *Male* | 23.98 (5.55) | 24.19 (5.72) | 24.22 (5.68) | | | | | | | | | |
| *Female* | 23.13 (5.96) | 23.75 (6.14) | 23.57 (6.23) | | | | | | | | | |
| **Age** | | | | 1.17 | 0.319 | 0.001 | 69.40 | <0.001 | 0.051 | 12.57 | <0.001 | 0.003 |
| *18-29* | 23.91 (5.73) | 24.35 (5.60) | 24.37 (5.78) | | | | | | | | | |
| *30-49* | 24.37 (5.76) | 24.96 (5.91) | 24.80 (5.82) | | | | | | | | | |
| *50-64* | 23.79 (5.61) | 24.09 (5.80) | 24.03 (5.96) | | | | | | | | | |
| *≥65* | 21.07 (5.38) | 21.24 (5.49) | 21.34 (5.58) | | | | | | | | | |
| **Occupation** | | | | 0.49 | 0.866 | 0.000 | 12.54 | <0.001 | 0.013 | 6.24 | 0.002 | 0.002 |
| *Employed* | 23.76 (5.51) | 24.13 (5.70) | 24.12 (5.69) | | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Homemaker* | 22.26 | (6.24) | 22.78 | (6.42) | 22.52 | (6.41) | | | | | |
| *Student* | 23.70 | (4.68) | 24.24 | (4.70) | 24.33 | (5.64) | | | | | |
| *Unemployed* | 23.81 | (6.33) | 24.15 | (6.28) | 23.99 | (6.41) | | | | | |
| *Other* | 25.02 | (5.97) | 25.79 | (6.41) | 25.58 | (6.53) | | | | | |
| **Marital status** | | | | | | | 0.55 | 0.58 | 0.000 | 286.11 <0.001 | 0.069 | 20.26 <0.001 | 0.005 |
| *Married* | 22.53 | (5.41) | 22.90 | (5.55) | 22.88 | (5.57) | | | | | |
| *Unmarried* | 25.46 | (5.88) | 25.91 | (6.07) | 25.75 | (6.16) | | | | | |
| **The presence of child** | | | | | | | 0.15 | 0.86 | 0.000 | 244.19 <0.001 | 0.059 | 21.54 <0.001 | 0.006 |
| *Yes* | 22.44 | (5.41) | 22.82 | (5.65) | 22.74 | (5.62) | | | | | |
| *No* | 25.03 | (5.86) | 25.46 | (5.93) | 25.41 | (6.03) | | | | | |
| **Annual household income (JPY)** | | | | | | | 0.72 | 0.68 | 0.001 | 29.91 <0.001 | 0.041 | 7.76 <0.001 | 0.003 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *< 2.0 million* | 26.85 | (6.38) | 27.03 | (6.29) | 26.96 | (6.60) |
| *2.0-3.9 million* | 24.12 | (5.92) | 24.62 | (6.11) | 24.42 | (6.04) |
| *4.0-5.9 million* | 23.45 | (5.67) | 23.82 | (5.77) | 23.62 | (5.74) |
| *6.0-7.9 million* | 23.21 | (5.49) | 23.54 | (5.88) | 23.75 | (5.88) |
| *≥ 8.0 million* | 22.45 | (5.58) | 22.68 | (5.65) | 22.66 | (5.81) |

Table 5. Results of linear mixed model analysis of psychosocial and physical factors associated with loneliness in the three phases

| | | | | | 95%CI | |
|---|---|---|---|---|---|---|
| | Estimate | SE | *t* | *p* | Lower | Upper |
| Intercept | 27.69 | 0.44 | 63.34 | <0.001 | 26.84 | 28.55 |
| Phase (*ref: Phase 3*) | | | | | | |
| *Phase 1* | -0.46 | 0.53 | -0.88 | 0.379 | -1.50 | 0.57 |
| *Phase 2* | -0.22 | 0.51 | -0.44 | 0.660 | -1.21 | 0.77 |
| **Sex (*ref: Female*)** | | | | | | |
| *Male* | 0.95 | 0.16 | 6.12 | <0.001 | 0.65 | 1.25 |
| **Marital status (*ref: Married*)** | | | | | | |
| *Unmarried* | 0.53 | 0.17 | 3.20 | 0.001 | 0.21 | 0.86 |
| **Annual household income (JPY) (*ref: ≥ 8.0 million*)** | | | | | | |
| *< 2.0 million* | 0.47 | 0.27 | 1.76 | 0.079 | -0.05 | 1.00 |
| *2.0-3.9 million* | -0.01 | 0.20 | -0.06 | 0.954 | -0.40 | 0.38 |
| *4.0-5.9 million* | -0.20 | 0.19 | -1.10 | 0.273 | -0.57 | 0.16 |
| *6.0-7.9 million* | -0.08 | 0.20 | -0.40 | 0.691 | -0.46 | 0.31 |
| **Age** | -0.04 | 0.01 | -6.25 | <0.001 | -0.05 | -0.03 |
| **K6** | 0.08 | 0.02 | 4.60 | <0.001 | 0.05 | 0.12 |
| **PHQ-9** | 0.10 | 0.02 | 5.02 | <0.001 | 0.06 | 0.14 |
| **SSS-8** | 0.05 | 0.02 | 3.04 | 0.002 | 0.02 | 0.08 |
| **LSNS-6** | -0.28 | 0.01 | -23.18 | <0.001 | -0.30 | -0.26 |
| **Exercise** | -0.12 | 0.04 | -3.21 | 0.001 | -0.19 | -0.05 |
| **Offline interaction with familiar people** | -0.29 | 0.04 | -7.08 | <0.001 | -0.37 | -0.21 |
| **Online interaction with familiar people** | -0.16 | 0.04 | -4.36 | <0.001 | -0.24 | -0.09 |
| **Altruistic preventive behavior** | 0.15 | 0.04 | 3.64 | <0.001 | 0.07 | 0.23 |
| **Optimism** | -0.47 | 0.05 | -9.33 | <0.001 | -0.57 | -0.37 |
| **Deterioration of household economy** | 0.14 | 0.04 | 3.19 | 0.001 | 0.05 | 0.22 |
| **Deterioration of relationship with familiar people** | 0.38 | 0.06 | 6.9 | <0.001 | 0.27 | 0.49 |
| **Frustration** | 0.28 | 0.05 | 5.4 | <0.001 | 0.18 | 0.38 |
| **Difficulty owing to the lack of daily necessities** | 0.03 | 0.05 | 0.61 | 0.541 | -0.07 | 0.13 |
| **Phase * Sex (*ref: Phase 3 and Female*)** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Phase 1 * Male* | 0.07 | 0.16 | 0.42 | 0.675 | -0.25 | 0.39 |
| *Phase 2 * Male* | -0.08 | 0.16 | -0.47 | 0.639 | -0.39 | 0.24 |
| **Phase * Marital status (*ref: Phase 3 and Married*)** | | | | | | |
| *Phase 1 * Unmarried* | 0.34 | 0.18 | 1.87 | 0.061 | -0.02 | 0.70 |
| *Phase 2 * Unmarried* | 0.43 | 0.18 | 2.41 | 0.016 | 0.08 | 0.78 |
| **Phase * Annual household income (JPY) (*ref: Phase 3 and ≥ 8.0 million*)** | | | | | | |
| *Phase 1 * < 2.0 million* | 0.13 | 0.34 | 0.39 | 0.697 | -0.53 | 0.79 |
| *Phase 1 * 2.0-3.9 million* | 0.38 | 0.23 | 1.61 | 0.107 | -0.08 | 0.84 |
| *Phase 1 * 4.0-5.9 million* | 0.46 | 0.22 | 2.08 | 0.037 | 0.03 | 0.89 |
| *Phase 1 * 6.0-7.9 million* | 0.15 | 0.25 | 0.60 | 0.547 | -0.33 | 0.63 |
| *Phase 2 * < 2.0 million* | -0.18 | 0.32 | -0.57 | 0.572 | -0.82 | 0.45 |
| *Phase 2 * 2.0-3.9 million* | 0.27 | 0.23 | 1.19 | 0.233 | -0.18 | 0.72 |
| *Phase 2 * 4.0-5.9 million* | 0.17 | 0.22 | 0.80 | 0.423 | -0.25 | 0.59 |
| *Phase 2 * 6.0-7.9 million* | 0.05 | 0.24 | 0.21 | 0.834 | -0.43 | 0.53 |
| **Phase * Age (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | 0.00 | 0.01 | 0.15 | 0.879 | -0.01 | 0.01 |
| *Phase 2* | 0.00 | 0.01 | 0.50 | 0.614 | -0.01 | 0.02 |
| **Phase * K6 (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | 0.05 | 0.03 | 2.08 | 0.037 | 0.00 | 0.11 |
| *Phase 2* | 0.00 | 0.03 | 0.10 | 0.921 | -0.05 | 0.05 |
| **Phase * PHQ-9 (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | 0.04 | 0.03 | 1.57 | 0.117 | -0.01 | 0.10 |
| *Phase 2* | 0.05 | 0.03 | 1.80 | 0.071 | 0.00 | 0.11 |
| **Phase * SSS-8 (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | -0.02 | 0.02 | -0.97 | 0.332 | -0.06 | 0.02 |
| *Phase 2* | -0.03 | 0.02 | -1.53 | 0.127 | -0.07 | 0.01 |
| **Phase * LSNS-6 (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | 0.01 | 0.02 | 0.63 | 0.527 | -0.02 | 0.04 |
| *Phase 2* | -0.03 | 0.01 | -1.88 | 0.060 | -0.06 | 0.00 |
| **Phase * Exercise (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | 0.04 | 0.05 | 0.86 | 0.391 | -0.05 | 0.14 |
| *Phase 2* | 0.03 | 0.05 | 0.55 | 0.585 | -0.07 | 0.12 |
| **Phase * Offline interaction with familiar people (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | 0.12 | 0.05 | 2.24 | 0.025 | 0.01 | 0.23 |
| *Phase 2* | 0.10 | 0.05 | 1.90 | 0.058 | 0.00 | 0.21 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Phase * Online interaction with familiar people (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | -0.03 | 0.05 | -0.61 | 0.540 | -0.13 | 0.07 |
| *Phase 2* | -0.04 | 0.05 | -0.71 | 0.480 | -0.14 | 0.06 |
| **Phase * Altruistic preventive behavior (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | -0.25 | 0.05 | -4.65 | <0.001 | -0.36 | -0.15 |
| *Phase 2* | -0.14 | 0.05 | -2.59 | 0.010 | -0.25 | -0.03 |
| **Phase * Optimism (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | 0.17 | 0.07 | 2.47 | 0.013 | 0.03 | 0.30 |
| *Phase 2* | 0.09 | 0.07 | 1.34 | 0.181 | -0.04 | 0.22 |
| **Phase * Deterioration of household economy (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | -0.06 | 0.06 | -1.16 | 0.247 | -0.17 | 0.04 |
| *Phase 2* | 0.08 | 0.06 | 1.45 | 0.146 | -0.03 | 0.19 |
| **Phase * Deterioration of relationship with familiar people (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | -0.13 | 0.07 | -1.83 | 0.067 | -0.28 | 0.01 |
| *Phase 2* | -0.14 | 0.07 | -1.97 | 0.049 | -0.29 | 0.00 |
| Phase * Frustration (*ref: Phase 3*) | | | | | | |
| *Phase 1* | -0.11 | 0.07 | -1.69 | 0.091 | -0.25 | 0.02 |
| *Phase 2* | -0.03 | 0.07 | -0.42 | 0.676 | -0.16 | 0.10 |
| **Phase * Difficulty owing to the lack of daily necessities (*ref: Phase 3*)** | | | | | | |
| *Phase 1* | 0.04 | 0.06 | 0.59 | 0.555 | -0.09 | 0.16 |
| *Phase 2* | 0.02 | 0.07 | 0.35 | 0.730 | -0.11 | 0.16 |

LSNS-6: Lubben Social Network Scale (abbreviated version); K6: Kessler Psychological Distress Scale-6; PHQ-9: Patient Health Questionnaire-9; Somatic Symptom Scale-8

# Supplementary Files

Untitled.
URL: http://asset.jmir.pub/assets/4750dc186c0a33ff01c1057c35b51428.docx

# Multimedia Appendixes

Items about lifestyle, coping behavior, and stressors related to COVID-19 pandemic.
URL: http://asset.jmir.pub/assets/bbeecf4e02ff79b7008c5e51d1d54dfb.docx