Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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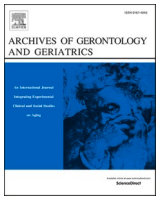

Physical, social, and dietary behavioral changes during the COVID-19 crisis and their effects on functional capacity in older adults

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ABSTRACT

Background: This two-year follow-up study aimed to identify factors associated with unhealthy behaviors during the COVID-19 pandemic and examine their impact on functional capacity in older adults.
Methods: Altogether, 536 adults aged ≥65 years participated in this study. The frequency of going out, exercise habits, face-to-face and non-face-to-face interactions, social participation, and eating habits were examined as behavioral factors before and after the first declaration of a state of emergency in Japan. Functional capacity was assessed using the Tokyo Metropolitan Institute of Gerontology Index of Competence.
Results: Using latent class analysis considering changes in the six behaviors, the participants were divided into healthy (n = 289) and unhealthy (n = 247) behavior groups. The male sex was associated with 2.36 times higher odds, diabetes with 2.19 times higher odds, depressive mood with 1.83 times higher odds, poor subjective economic status with 2.62 times higher odds, and living alone with 44% lower odds of being unhealthy. The unhealthy behavior group showed significantly decreased functional capacity (B =−1.56 [−1.98, −1.14]) than the healthy behavior group. For each behavior, negative changes in going out (B =−0.99 [−1.60, −0.37]), face-to-face interaction (B =−0.65 [−1.16, −0.13]), and non-face-to-face interactions (B =−0.80 [−1.36, −0.25]) were associated with a decline in functional capacity.
Conclusion: Our results showed four factors associated with engaging in unhealthy lifestyle behaviors and how behavioral changes affect functional capacity decline during the COVID-19 pandemic, which will help to develop public health approaches

1. Introduction

The coronavirus disease 2019 (COVID-19) and concomitant measures have had large impact on various aspects from 2020 to 2021 (Clemente-Suárez et al., 2020). Many people have had to change their lifestyle behaviors due to restrictions such as self-quarantine and curfews. The intensity of the preventive measures for COVID-19 differed by country; fines were imposed when people violated the rules in some countries (and states) such as the UK, the US, and Australia, while no punishment was imposed in Japan even if people did not follow the recommendations related to a declaration of the state of emergency. A typical policy was staying at home, which resulted in the loss of opportunities to go out. Consequently, a decrease in physical activity is a common phenomenon in many cities, despite differences in policy measures (Silva et al., 2021; Tison et al., 2020). Meanwhile, the importance of a physically active lifestyle has been acknowledged (World Health Organization, 2020).

Another crucial impact of the COVID-19 pandemic was found on

Abbreviations: AIC, Akaike information criterion; BIC, Bayesian information criterion; COVID-19, coronavirus disease 2019; DVS, dietary variety score; LCA, latent class analysis; TMIG-IC, Tokyo Metropolitan Institute of Gerontology Index of Competence.

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social aspects. The COVID-19 pandemic has provoked social isolation and loneliness, and in this situation, older adults are likely to be more vulnerable than younger adults (Murayama et al., 2021; Wu, 2020). Social participation, defined as participation in social activity groups (Douglas et al., 2017), is encouraged to prevent adverse health outcomes (Abe et al., 2020; Kanamori et al., 2014). Intermittence with social activities was inevitable, particularly when increasing the number of positive cases. Therefore, behavioral changes in social aspects during the COVID-19 pandemic could trigger functional decline.

People's behaviors may gradually return to normal after passing the peak of new COVID-19 cases. A Japanese internet survey involving older adults aged ≥65 years with three time points—before, during, and after the first declaration of a state of emergency—suggested a V-shaped trend in physical activity, which indicates that physical activity decreased at the survey conducted during the first declaration of a state of emergency but recovered after it was lifted (Yamada et al., 2020). Nevertheless, the physical activity of those living alone and socially inactive did not recover. A previous Chinese study that examined smartphone-based step counts reported that the step counts rapidly decreased at the early stage of the lockdown, but steadily increased as the end of the lockdown approached (Ding et al., 2021). Other observational data from Luxembourg have indicated that the number of daily social contacts significantly increased in the post-lockdown period compared to that during the lockdown period (Latsuzbaia et al., 2020). These two studies from China and Luxembourg have reported that older adults were less likely to slowly recover their lifestyle behaviors than younger adults after the end of the lockdown. Hence, changes in lifestyle behaviors could be highlighted only during the restricted period, although some older adults could continue to engage in unhealthy lifestyle behaviors after the restrictions eased. These previous studies examined one aspect of daily lifestyle; however, focusing on multiple behaviors would be more effective in preventing adverse health outcomes (Seino et al., 2021; Haider et al., 2020). Therefore, considering multiple behaviors during the prolonged COVID-19 pandemic to identify older adults with unhealthy daily lifestyles is crucial. Eating habits are also unavoidable in this context, as they are considered one of the factors that contribute to a healthy lifestyle. Previous reports on the impact of the COVID-19 pandemic on diet vary (Nicklett et al., 2021; Elisabeth et al., 2021), which may be due to the difference in COVID-19-related policies in each country. Hence, reporting from various regions may be necessary when synthesizing findings on changes in eating habits associated with the COVID-19 pandemic.

Moreover, understanding the longitudinal relationships of such behavioral changes due to the pandemic with health outcomes is important when considering health promotion approaches looking ahead of the post-COVID era. Functional capacity is a reasonable outcome in studies with a short follow-up period, as it is a well-established predictor of adverse health outcomes such as mortality (Taniguchi et al., 2019). Changes in functional capacity precede a decline in basic function (Fujiwara et al., 2003). Therefore, functional capacity is a sensible marker for understanding early functional changes. This study aimed to identify those who were vulnerable in terms of lifestyle behaviors after the first COVID-19 crisis in Japan and examine the relationships between behavioral changes before and after the crisis and functional capacity in older adults.

2. Materials and methods

2.1. Participants

This prospective study used data from the Kusatsu Longitudinal Study on Ageing, which started in 2001 in Kusatsu town, Gunma Prefecture. The concept of the Kusatsu study is described elsewhere (Shinkai et al., 2016). For the Kusatsu study, health checkups were conducted annually, and a complete survey was conducted every three years, with the support of Kusatsu town. The health checkups were conducted for older adults aged 65-74 years who enrolled on the National Health Insurance system and those aged 75 years and older who were registered with the Medical System for Older Senior Citizens in Japan. These were equivalent to the inclusion criteria for the Kusatsu study, and this scheme allowed older adults to participate in the health checkups again even if they did not attend them for several years. The target for the checkups was approximately 2,000-2,500 older adults every year. Here, we used the data collected in July 2019 and July 2020 to evaluate the changes in lifestyle behaviors before and after the first COVID-19 crisis and that from 2019 to 2021 to assess changes in functional capacity. A total of 747 participants aged ≥ 65 years underwent a health check-up in 2019. Those with disabilities identified by the Japanese long-term care insurance (Tsutsui & Muramatsu, 2007) (i.e., those requiring any support or care in daily life) (n = 53) and those with missing variables on an outcome (n = 71) or exposures (n = 57) at baseline were excluded. Consequently, 566 older adults were potentially eligible at baseline. A follow-up mailed survey was conducted in 2020, when the first declaration of a state of emergency for Gunma Prefecture from April 16, 2020 to May 14, 2020 was lifted. Moreover, both mailed and on-site surveys were conducted from mid-June to the beginning of July 2021. This study was approved by the ethics committee of the Tokyo Metropolitan Institute of Gerontology (TMIG). Written informed consent was obtained from all the participants.

2.2. Outcome

The primary outcome was functional capacity assessed using the TMIG Index of Competence (TMIG-IC) (Koyano et al., 1991). This index comprises 13 yes/no questions and covers the following three subcategories based on Lawton's model: instrumental self-maintenance, intellectual activity, and social role. Appendix 1 provides details of this index. A higher TMIG-IC score indicates higher functional capacity.

2.3. Exposures

This study focused on two physical and three social aspects of lifestyle behaviors. We used the frequency of going out and exercise habits for physical aspects. The following five options were indicated for the frequency of going out: ≥2 times/day, 1 time/day, 1 time/2–3 days, 1 time/week, and rarely. The answers were dichotomized into high frequency (≥1 times/day) and low frequency (<1 time/day) (Sakurai et al., 2019). Six options were provided for exercise habits: ≥5 times/week, 3–4 times/week, 1–2 times/week, 1–3 times/month, <1 time/month, and never exercised. According to the operational definition of low activity (Satake & Arai, 2020), we defined active as ≥1 times/week and inactive as <1 time/week. We asked participants regarding the frequency of face-to-face interactions with friends, neighbors, and family or relatives who lived in another place. The options were as follows: ≥2 times/week, 1 time/week, 2–3 times/month, 1 time/month, <1 time/month, and no such person. Non-face-to-face interactions were assessed in a similar manner. Both types of interactions were defined as interaction (≥1 time/week) and non-interaction (<1 time/week) (Fujiwara et al., 2017; Sakurai et al., 2019). Participants were asked whether they participated in social activities (e.g., volunteering, sports, hobbies, senior clubs, and neighborhood associations). Participation was defined as participation in any social activity at least once per month (Saito et al., 2017). Eating habits were assessed using the dietary variety score (DVS) (Kumagai et al., 2003). The participants were asked whether they had consumed the following 10 items in the past week: meat, fish/shellfish, eggs, milk, soybean products, green/yellow vegetables, potatoes, fruit, seaweed, and fats/oil. One point was given when the response was "almost daily" for each item, and the total score was computed. A conventional cutoff point for the DVS was used to define sufficiency (≥4 points) and insufficiency (≤3 points) (Kumagai et al., 2003; Yokoyama et al., 2017).

2.4. Covariates

Referring to previous studies (Fujiwara et al., 2003; Taniguchi et al., 2019), data on age, sex, education, medical history, presence of knee and back pain, visual impairment, smoking, living arrangement, depressive mood, and subjective economic status were collected at baseline. Medical history included hypertension, hyperlipidemia, diabetes, stroke, heart disease, cancer, and osteoporosis. Depressive mood was assessed using the Geriatric Depression Scale sort-form with a cut-off score of ≥6 (Niino et al., 1991; Schreiner et al., 2003).

2.5. Statistical analysis

Behavioral changes from the 2019 to 2020 surveys were described in four categories: persistence of healthy lifestyle behavior, positive change (unhealthy lifestyle behavior to healthy lifestyle behavior), negative change (healthy lifestyle behavior to unhealthy lifestyle behavior), and persistence of unhealthy behavior.

Latent class analysis (LCA) was conducted to identify subgroups. We calculated the Bayesian information criterion (BIC) and the Akaike information criterion (AIC) to determine the appropriate number of classes. This study prioritized BIC over AIC, referring to a guide for LCA (Weller et al., 2020). We then applied a generalized linear model to examine the factors associated with the classes.

We used multilevel Tobit models to examine the relationships between the classes identified by LCA and changes in each lifestyle behavior with functional capacity, as ceiling effects were observed in the outcome variable. Model 1 was unadjusted. Model 2 included one exposure variable and the aforementioned covariates. In Model 3, the covariates were the same as those in Model 2, although each lifestyle behavior was entered simultaneously. All analyses were conducted using Stata ver. 17 (STATA Corp, College Station, TX, USA).

3. Results

After excluding 49 participants with missing data regarding covariates or behavioral factors in 2020 from the analysis, 517 participants remained in the analytical sample. Table 1 presents the characteristics of the participants. At baseline, the range of the TMIG-IC was 5 to 13 (median = 12; Q1, Q3 = 11, 13), and 41% of the participants had the maximum score.

We increased the number of classes in the LCA, although we did not confirm five or more models, as the four-class model was no longer convergent. The AIC and BIC were 7261 and 7337 for the one-class model, 7055 and 7212 for the two-class model, and 7029 and 7267 for the three-class model. We adopted a two-class model, which demonstrated the lowest BIC among these models. Item response probabilities are presented in Appendix 2.

Table 2 lists the proportion of each behavioral change. Relative to the social aspects, the physical and dietary aspects tended to remain consistent between the two time points. For the two groups based on the results of LCA, one group was mainly composed of those who engaged in healthy behavior at the one-year follow-up survey (i.e., the healthy behavior group), and the other group comprised those who did not,

Table 1
Characteristics of the participants at baseline.

Age, yrs			74.7 ± 5.7
Men		n (%)	212 (41.0)
BMI, kg/m^2			
	<18.5	n (%)	40 (7.7)
	18.5–24.9	n (%)	340 (65.8)
	≥25.0	n (%)	137 (26.5)
Living alone		n (%)	163 (31.5)
Education, yrs			
	<12	n (%)	237 (45.8)
	≥12	n (%)	280 (54.2)
Hypertension		n (%)	220 (42.6)
Hyperlipidemia		n (%)	171 (33.1)
Diabetes		n (%)	64 (12.4)
Cancer		n (%)	55 (10.6)
Stroke		n (%)	18 (3.5)
Heart disease		n (%)	54 (10.4)
Osteoporosis		n (%)	52 (10.1)
Knee pain		n (%)	181 (35.0)
Back pain		n (%)	193 (37.3)
Visual impairment		n (%)	19 (3.7)
Current smoking		n (%)	56 (10.8)
Depressive moods		n (%)	89 (17.2)
Subjective economic status			
Good		n (%)	49 (9.5)
Fair		n (%)	401 (77.6)
Poor		n (%)	67 (13.0)

Table 2
Proportion of physical and social behavior changes from 2019 to 2020.

		All (n = 517)	Class 1 (n = 291)	Class 2 (n = 226)
Going out				
High frequency - High frequency	n (%)	322 (62.3)	204 (70.1)	118 (52.2)
Low frequency - High frequency	n (%)	54 (10.4)	33 (11.3)	21 (9.3)
High frequency - Low frequency	n (%)	56 (10.8)	28 (9.6)	28 (12.4)
Low frequency - Low frequency	n (%)	85 (16.4)	26 (8.9)	59 (26.1)
Exercise habits				
Active-Active	n (%)	350 (67.7)	232 (79.7)	118 (52.2)
Inactive-Active	n (%)	61 (11.8)	27 (9.3)	34 (15.0)
Active-Inactive	n (%)	38 (7.4)	15 (5.2)	23 (10.2)
Inactive-Inactive	n (%)	68 (13.2)	17 (5.8)	51 (22.6)
Face-to-face interactions				
Interaction - Interaction	n (%)	147 (28.4)	147 (50.5)	0 (0.0)
Non-interaction - Interaction	n (%)	45 (8.7)	25 (8.6)	20 (8.8)
Interaction - Non-interaction	n (%)	164 (31.7)	101 (34.7)	63 (27.9)
Non-interaction - Non-interaction	n (%)	161 (31.1)	18 (6.2)	143 (63.3)
No-face-to-face interactions				
Interaction - Interaction	n (%)	275 (53.2)	245 (84.2)	30 (13.3)
Non-interaction - Interaction	n (%)	50 (9.7)	8 (2.7)	42 (18.6)
Interaction - Non-interaction	n (%)	91 (17.6)	34 (11.7)	57 (25.2)
Non-interaction - Non-interaction	n (%)	101 (19.5)	4 (1.4)	97 (42.9)
Social participation				
Participation - Participation	n (%)	230 (44.5)	185 (63.6)	45 (19.9)
Non-participation - Participation	n (%)	84 (16.3)	36 (12.4)	48 (21.2)
Participation - Non-participation	n (%)	52 (10.1)	28 (9.6)	24 (10.6)
Non-participation - Non-participation	n (%)	151 (29.2)	42 (14.4)	109 (48.2)
Eating habits				
Sufficiency – Sufficiency	n (%)	211 (40.8)	132 (45.4)	79 (35.0)
Insufficiency - Sufficiency	n (%)	62 (12.0)	39 (13.4)	23 (10.2)
Sufficiency - Insufficiency	n (%)	50 (9.7)	27 (9.3)	23 (10.2)
Insufficiency - Insufficiency	n (%)	194 (37.5)	93 (32.0)	101 (44.7)

particularly in social aspects (i.e., the unhealthy behavior group).

Class 1 and Class 2 indicate the healthy and unhealthy behavior groups, respectively.

As the participants were divided into two groups, we performed a logistic regression analysis (Table 3). The male sex was associated with 2.36 times higher odds, diabetes with 2.19 times higher odds, depressive mood with 1.83 times higher odds, and poor subjective economic status with 2.62 times higher odds of being in the unhealthy behavior group. Conversely, living alone was associated with 44% lower odds of being in the unhealthy behavior group.

Table 4 summarizes the relationships between the classification based on LCA and each behavioral change with functional capacity. The total observation was 1,476. Being the unhealthy group was associated with functional capacity decline (B=−1.56, [95% confidence interval: −1.98, −1.14]) after adjusting for covariates. Persistence of unhealthy behaviors was associated with a functional capacity decline in Model 3, irrespective of the type of behavior. Positive changes in social participation (B=−0.69 [−1.26, −0.12]), negative changes in going out (B=−0.99 [−1.60, −0.37]), face-to-face interaction (B=−0.65 [−1.16, −0.13]), and non-face-to-face interactions (B=−0.80 [−1.36, −0.25]) were associated with a decline in functional capacity.

Model 1: Each exposure was included separately without adjustment; Model 2: each exposure was included separately with adjustment for age, sex, education, medical history, presence of knee and back pain, visual impairment, smoking, living arrangement, depressive mood, and subjective economic status; Model 3: each exposure was included simultaneously with adjustment for the same covariates as in Model 2.

4. Discussion

This study demonstrated three findings: first, behavioral changes before and after the first declaration of a state of emergency are likely to emphasize more on social aspects, rather than physical and dietary ones; second, older men, and those with diabetes, depressive mood, or poor subjective economic status were less likely to engage in healthy lifestyle behaviors under the COVID-19 pandemic situation even after the first declaration of a state of emergency was lifted; last, not only the persistence of unhealthy behaviors but also negative behavioral changes regarding going out and social interactions were associated with functional capacity decline.

Since the impacts of activity restrictions, such as quarantines and curfews, on physical activity, social interactions, and diet behaviors were one of the main focuses in the early days of the COVID-19 pandemic, diverse findings on these topics have been reported from

Table 3
Associations of individual factors with the unhealthy behavior group (class 2).

Factors	Status	OR (95% CI)
Age	≥75 yrs.	1.20 (0.81, 1.80)
Gender	Men	2.36 (1.55, 3.58)
BMI	< 18.5 kg/m2	1.73 (0.84, 3.59)
	≥25.0 kg/m2	1.08 (0.69, 1.68)
Living arrangement	Living alone	0.56 (0.37, 0.85)
Education	<12 yrs.	0.88 (0.59, 1.30)
Hypertension	Yes	0.80 (0.53, 1.30)
Hyperlipidemia	Yes	0.94 (0.62, 1.43)
Diabetes	Yes	2.19 (1.24, 3.89)
Cancer	Yes	0.71 (0.38, 1.33)
Stroke	Yes	1.64 (0.58, 4.61)
Heart disease	Yes	0.84 (0.44, 1.59)
Osteoporosis	Yes	0.93 (0.48, 1.77)
Knee pain	Yes	1.51 (0.97, 2.34)
Back pain	Yes	1.19 (0.78, 1.81)
Visual impairment	Yes	0.62 (0.22, 1.70)
Current smoking	Yes	1.25 (0.67, 2.33)
Mental health	Depressive mood	1.83 (1.10, 3.06)
Subjective economic status	Fair	0.96 (0.50, 1.82)
	Poor	2.62 (1.15, 5.95)

Table 4
Associations of behavioral changes in physical, social, and dietary aspects with functional capacity

		Model 1 β (95% CI)	Model 2 β (95% CI)	Model 3 β (95% CI)
Group	Healthy behavior group	Ref.	Ref.	N/A
	Unhealthy behavior group	-1.89 (-2.31, -1.46)	-1.56 (-1.98, -1.14)	
Each lifestyle behavior				
Going out	High frequency - High frequency	Ref.	Ref.	Ref.
	Low frequency - High frequency	-0.58 (-1.31, 0.16)	-0.65 (-1.31, 0.01)	-0.51 (-1.12, 0.10)
	High frequency - Low frequency	-1.07 (-1.79, -0.34)	-1.14 (-1.80, -0.48)	-0.99 (-1.60, -0.37)
	Low frequency - Low frequency	-0.93 (-1.54, -0.32)	-1.13 (-1.69, -0.58)	-0.67 (-1.20, -0.14)
Exercise habits	Active - Active	Ref.	Ref.	Ref.
	Inactive - Active	-1.06 (-1.75, -0.37)	-0.88 (-1.53, -0.23)	-0.41 (-1.01, 0.20)
	Active - Inactive	-0.23 (-1.08, 0.61)	-0.08 (-0.86, 0.71)	0.50 (-0.25, 1.24)
	Inactive - Inactive	-1.42 (-2.08, -0.76)	-1.34 (-1.96, -0.72)	-0.59 (-1.18, -0.001)
Face-to-face interactions	Interaction - Interaction	Ref.	Ref.	Ref.
	Non-interaction - Non-interaction	-0.84 (-1.65, -0.04)	-0.78 (-1.53, -0.02)	-0.40 (-1.14, 0.34)
	Interaction - Non-interaction	-1.37 (-1.91, -0.83)	-1.18 (-1.69, -0.67)	-0.65 (-1.16, -0.13)
	Non-interaction - Non-interaction	-2.19 (-2.73, -1.64)	-1.85 (-2.38, -1.32)	-0.84 (-1.42, -0.27)
No-face-to-face interactions	Interaction - Interaction	Ref.	Ref.	Ref.
	Non-interaction - Non-interaction	-0.82 (-1.54, -0.10)	-0.73 (-1.41, -0.05)	-0.23 (-0.91, 0.45)
	Interaction - Non-interaction	-1.54 (-2.11, -0.97)	-1.33 (-1.88, -0.78)	-0.80 (-1.36, -0.25)
	Non-interaction - Non-interaction	-2.32 (-2.87, -1.78)	-2.03 (-2.57, -1.50)	-1.23 (-1.82, -0.64)
Social participation	Participation - Participation	Ref.	Ref.	Ref.
	Non-participation - Participation	-1.24 (-1.86, -0.61)	-1.16 (-1.76, -0.57)	-0.69 (-1.26, -0.12)
	Participation - Non-participation	-0.97 (-1.72, -0.22)	-0.89 (-1.60, -0.18)	-0.38 (-1.06, 0.29)
	Non-participation - Non-participation	-1.53 (-2.04, -1.01)	-1.33 (-1.81, -0.85)	-0.55 (-1.04, -0.07)
Eating habits	Sufficiency - Sufficiency	Ref.	Ref.	Ref.
	Insufficiency - Sufficiency	-0.57 (-1.28, 0.14)	-0.27 (-0.95, 0.40)	-0.31 (-0.93, 0.31)
	Sufficiency - Insufficiency	-1.04 (-1.82, -0.26)	-0.50 (-1.23, 0.24)	-0.45 (-1.11, 0.22)
	Insufficiency - Insufficiency	-1.28 (-1.77, -0.79)	-0.75 (-1.24, -0.27)	-0.53 (-0.97, -0.09)

various regions (Ding et al., 2021; Latsuzbaia et al., 2020; Nicklett et al., 2021; Elisabeth et al., 2021; Tison et al., 2020; Yamada et al., 2020). Our descriptive findings regarding behavioral changes before and after the first declaration of a state of emergency are one report from a rural area in Japan. One of the features of this study was the number of behavioral factors. Due to this feature, our findings suggest that behavioral changes in social aspects, especially a negative change in social interaction, may be striking compared to those in physical and dietary aspects. This could be attributed to the characteristics of this study. Kusatsu town, from which we collected data, is located in Gunma prefecture, where the total number of positive cases of COVID-19 until the end of July 2020, when our one-year follow-up survey was completed, was <10 persons/100, 000 population (Gunma Prefecture, 2020). Most residents there could have gone out, exercised, and accessed food during the follow-up period in such a relatively non-severe situation, although they might have avoided meeting someone in person and participating in social activities for their safety and protection against COVID-19.

Although the number of classes could depend on the analytical sample, the participants were divided into healthy and unhealthy behavior groups using LCA. This finding is plausible as some people can adjust to the situation during the COVID-19 pandemic, while some cannot. A Canadian study has reported that 36% of the participants became more physically active after the restrictions related to the COVID-19 pandemic were enforced (Lesser & Nienhuis, 2020). In situations where it is difficult to interact face-to-face, some older adults are likely to find ways, such as text, e-mail, and videocall, to contact someone (Freedman et al., 2021). Conducting a study with a large sample size that has the potential to classify the sample into three or more groups may be necessary to identify behavior-specific tendencies and provide more useful information.

Previous studies have identified factors associated with changes in specific behaviors in the context of the COVID-19 pandemic (Ding et al., 2021; Naughton et al., 2021). By contrast, our study attempted to identify factors associated with a comprehensive healthy lifestyle behavior considering physical, social, and dietary aspects, as focusing on multiple behavioral factors is important when considering health approaches (Seino et al., 2021; Haider et al., 2020). Our findings highlighted that the four significant factors (Table 3) may be useful in identifying older adults who are vulnerable to daily behavior and are likely to decrease their functional capacity during the COVID-19 pandemic. The male sex, diabetes, and poor economic status are associated with an increased risk of infection and severity of COVID-19 (Munõz-Price et al., 2020; Yu et al., 2020), and the mental health of older adults with depressive moods may worsen during the COVID-19 pandemic (Ettman et al., 2020). Consequently, these factors might incite excessive self-regulation, such as not going out and not meeting someone. Meanwhile, older adults living alone were associated with not engaging in unhealthy behaviors. Most participants had high functional capacity at baseline, suggesting that those living alone may not need to live with others, as they do not require any support in daily life. Such situation is likely to make them do everything, which may require going out for some purpose and bringing a chance to interact with others.

Our results highlight that unhealthy behavior during the COVID-19 pandemic is associated with functional capacity decline, even in the short follow-up period. This finding is fundamental to enforcing public health approaches to prevent functional capacity decline. Interpretation of the results of social participation requires caution, as our results showed a significant relationship between positive changes in social participation and decline in functional capacity. The effects of social participation could depend on the type of social activity (Abe et al., 2022; Kanamori et al., 2014), and unwilling social participation may have negative effects (Nonaka et al., 2019). Not considering these factors in this study may have led to the unexpected results.

The strength of this study was that we analyzed the data collected annually from before the COVID-19 pandemic to when it had been over a year, which enabled us to demonstrate the relationship between behavioral changes due to the COVID-19 pandemic and functional capacity decline. However, this study had several limitations. First, all exposures were based on subjective assessments and were dichotomized, irrespective of their contents. This may have led to less accurate categorization, although we used cut-off points based on previous findings. Second, the COVID-19 pandemic and its related measures, particularly the first declaration of a state of emergency, affected the participants' behavior. This premise is plausible, although we could not detect a difference between natural behavioral changes and changes due to the COVID-19 pandemic. Using a sophisticated analysis to demonstrate causal inference is needed to estimate the impact of COVID-19 on functional capacity decline through behavioral changes. Last, our results cannot be generalized beyond the analyzed population as COVID-19 measures depend on the country and region.

5. Conclusions

Negative behavioral changes, particularly regarding going out and social interactions, during the COVID-19 pandemic should be considered as they are associated with a decline in functional capacity in older adults. In this context, the male sex, diabetes, depressive mood, and poor subjective economic status could be useful factors to identify those who are prone to a deterioration in their functional capacity throughout their daily behaviors. Positive behavioral changes are likely to diminish the negative effects of temporally unfavorable behavior on functional capacity. Therefore, the importance of promoting healthy behaviors as a public health approach should be emphasized, particularly during the COVID-19 pandemic and even after it.

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CRediT authorship contribution statement

Takumi Abe: Conceptualization, Data curation, Formal analysis, Writing – original draft. **Yu Nofuji:** . **Satoshi Seino:** Data curation, Formal analysis, Writing – review & editing. **Toshiki Hata:** Data curation, Formal analysis, Writing – review & editing. **Miki Narita:** Data curation, Writing – review & editing. **Yuri Yokoyama:** Data curation, Writing – review & editing. **Hidenori Amano:** Data curation, Writing – review & editing. **Akihiko Kitamura:** Conceptualization, Data curation, Formal analysis, Writing – original draft. **Shoji Shinkai:** Conceptualization, Data curation, Formal analysis, Writing – original draft. **Yoshinori Fujiwara:** Conceptualization, Data curation, Formal analysis, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.archger.2022.104708.

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