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Regular Article

Title: Association between changes in the implementation of group exercise and incidence of frailty among Japanese non-frail older adults: 2018 and 2020 surveys including the COVID-19 pandemic

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Association between group exercise and frailty

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Abstract

The coronavirus disease 2019 (COVID-19) pandemic has hampered group exercise. We aimed to determine the relationship between group-exercise implementation status in 2018 and 2020 and the incidence of frailty in 2020, including the COVID-19 pandemic among older adults in Japan. This longitudinal study included older adults belonging to senior clubs, divided into four groups based on the continuity of group-exercise participation. Frailty was assessed using the Kihon Checklist; total scores of ≥8 points indicated frailty status. The relationship between group-exercise implementation status and the incidence of frailty was evaluated using Poisson regression with robust variance. Exercise time at the individual level in each group was analyzed using Wilcoxon signed-rank tests. Overall, 1,241 participants were included; 249 individuals (20.1%) newly developed frailty. Compared with older adults who continued group exercise, those who discontinued group exercise (adjusted relative risk: 1.70, 95% confidence interval: 1.26–2.30) was more likely to become frail. Regarding the median exercise time (interquartile range), older adults who discontinued group exercise showed a significant decrease, from 25.7 (12.9–51.7) min/day to 17.1 (6.4–30.0) min/day; those who started group exercise showed a significant increase from 19.3 (6.4–41.4) min/day to 20.0 (6.4–47.6) min/day. Group-exercise implementation status in 2018 and 2020 was associated with the incidence of frailty in 2020, including the COVID-19 pandemic. Supporting group exercise is important for

the prevention of frailty, even under social restrictions owing to infectious diseases.

Keywords: frailty, regular exercise, exercise time, infectious diseases, older adults

邦題: フレイル非該当の日本人高齢者におけるグループ運動の実施状況の変化とフレイル発症率の関連：新型コロナウイルスパンデミックを含む 2018 年および 2020 年の調査

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要旨:

新型コロナウイルスの流行により、グループ運動の実施が妨げられた。我々は、日本の高齢者における 2018 年と 2020 年のグループ運動の実施状況と新型コロナウイル

スの流行を含む 2020 年のフレイル発症との関連を明らかにすることを目的とした。本研究では、シニアクラブに所属する高齢者を対象とし、グループ運動への実施状況に基づいて 4 つのグループに分けた（継続群、中止群、開始群、非実施群)。フレイルは基本チェックリストを用いて評価し、合計得点が 8 点以上でフレイルに該当するとした。グループ運動の実施状況とフレイル発症との関係は、ロバスト分散を用いたポアソン回帰分析を用いて評価した。各群の個人レベルでの運動時間は、Wilcoxon 符号順位検定を用いて解析した。全体で 1,241 人が対象となり、249 人（20.1％）が新たにフレイルを発症した。継続群と比較して、中止群（調整済みリスク比：1.70, 95％信頼区間：1.26-2.30）はフレイルに発症する可能性が高かった。運動時間の中央値（四分位範囲）については、中止群は 25.7（12.9-51.7）分／日から 17.1（6.4-30.0）分／日と有意な減少を示し、開始群は 19.3（6.4-41.4）分／日から 20.0（6.4-47.6）分／日と有意に増加した。グループ運動の実施状況は、新型コロナウイルス流行を含む 2020 年のフレイル発症と関連していた。感染症による社会的制約がある中でも、グループ運動を支援することは、フレイル予防のために重要である。

キーワード: フレイル、運動習慣、運動時間、感染症、高齢者

Introduction

In March 2020, the World Health Organization declared the coronavirus disease (COVID-19) pandemic [1]; in response, restrictions were placed on outdoor activities and group gatherings, and social distancing was required, leading to marked changes in lifestyle and social behavior [2]. In April 2020, the Japanese government implemented a state of emergency as a preventive measure against the spread of the infection, urging citizens to refrain from social interactions [3,4]. As being older is a risk factor for serious complications from COVID-19 [5], older adults were particularly limited in their social interactions.

The proportion of individuals aged ≥ 65 years reached 29.0% of the total Japanese population in 2023, and approximately one in three adults will be ≥ 65 years of age by 2035 [6]. A cohort study conducted in Takasaki, Gunma, Japan, showed that 9.8% of Japanese older adults transitioned to frailty during the 6 months of the COVID-19 pandemic [7]. Additionally, an online survey of older adults, aged 65 to 84, registered with a survey company and living in various urban areas across Japan found that 16% had become frail within one year [8]. Frailty defined as "a state of increased vulnerability to various stresses due to a decline in physiological reserve capacity with aging" [9]. Frailty is a multidimensional concept, encompassing various physical, psychological, and social elements [10] and is associated with the deterioration of neurological, sensory, and musculoskeletal systems, consequently increasing the likelihood of hip fracture [11,12], falls [11,12], and low-trauma fragility fractures [13]. Considering that Japan is a rapidly aging

society, the increasing prevalence of frailty poses a significant burden; and its prevention is an urgent concern.

Exercise is recommended to help prevent frailty [14], and group exercise can encourage older adults to participate in exercise and improve their physical function compared to working individually using motivating factors such as social support [15, 16]. Therefore, these studies suggest that engaging in exercise in a group rather than alone is effective in preventing frailty. Furthermore, group exercise is beneficial not only for physical aspects, but also for mental and social health. A qualitative study to understand how older adults experience group exercise found that group exercise is beneficial to the social, physical, and mental health [17]. Although the participants recognized that they were getting older physically and cognitively, in addition to socializing with peers and enjoying life, regular group exercise helped maintain and improve functional health [17]. In addition, it has been shown to have beneficial effects on subjective health [18], exercise adherence [19,20], and social connections [20]. These findings suggest that voluntary group exercise among older community-living adults may be effective in preventing frailty.

While the COVID-19 pandemic has hampered participation in group exercise, no study has examined the relationship between group-exercise implementation status and the incidence of frailty during the pandemic. An association between group exercise and frailty will provide

38 insight into the significance of older adults continuing group exercise even under social
39 restrictions, such as during the COVID-19 pandemic. We hypothesized that the incidence of
40 frailty would differ according to group-exercise practices during the COVID-19 pandemic. In
41 this study, we aimed to determine the relationship between group-exercise implementation
42 status in 2018 and 2020 and the incidence of frailty in 2020, including the COVID-19 pandemic
43 among older adults in Japan.
44
45 **Material and methods**
46 Study design and participants
47 This longitudinal study involved older adults who were members of the Fujisawa City
48 Federation of Senior Citizens Clubs, a voluntary group organization comprising 127 senior
49 clubs located in Fujisawa City, Kanagawa, Japan (area: 69.57 km^2; population: 442,892; and
50 population of individuals aged ≥ 65 years: 108,472 [24.5%], as of April 2022). Senior clubs
51 are organizations in which older adults voluntarily engage in social activities such as exercise,
52 hobbies, and volunteer work. Senior clubs are organized not only in Fujisawa City, but also in
53 other areas of Japan. The study population comprised 5,839 senior club members, based on
54 membership information held by the association office of Fujisawa City. A questionnaire
55 survey was distributed to all members in collaboration with representatives from each senior

club and returned to the research coordinator by mail. The baseline survey was conducted in August–November 2018; the follow-up survey was conducted in September–November 2020. On the basis of the assessment using the Kihon checklist (KCL) [21], the respondents who exhibited frailty (KCL ≥ 8) during the baseline survey were excluded as the focus of this study was on the prevention of frailty. This study focused on the incidence of frailty. Distinguishing "frailty" from other conditions such as "robust" and "pre-frail" is crucial, as it enables us to specifically target individuals with more serious health conditions. Participants with unknown group exercise status in either or both the baseline and follow-up surveys were also excluded. In addition, those with missing data on age, sex, body mass index (BMI), living arrangements, work, self-rated health, perceived household economic status, smoking, alcohol consumption, social activity and exercise habits at baseline were excluded.

Measures

Group exercise

In this study, group exercise was defined as voluntary exercise conducted in groups of three or more people. During both the baseline and follow-up surveys, the participants were asked whether they engaged in group exercises, using the following question: "Do you participate in voluntary exercise conducted in groups of three or more people (group exercise)?" Participants

were required to answer either "Yes" or "No." Those who answered "Yes" at both baseline and the follow-up were categorized as "continuers;" those who answered "Yes" at baseline but "No" at the follow-up were categorized as "discontinuers;" those who answered "No" at baseline but "Yes" at the follow-up were categorized as "initiators," and those who answered "No" at both baseline and the follow-up were categorized as "non-initiators."

Frailty

Frailty was assessed using the KCL [21], a self-assessment questionnaire with "yes" or "no" answers to 25 questions in seven categories: activities of daily living, physical function, nutrition, oral function, outdoor activities, cognitive function, and depression. One point was added to the score if the participants had problems with functions in daily life; the higher the score, the more problems they had with these daily living functions. Total scores of 0–3, 4–7, and ≥ 8 points indicated robust, pre-frailty, and frailty statuses, respectively; the number of frailty phenotypes defined by the Cardiovascular Health Study criteria [22] correlated closely with total KCL scores. KCL is frequently used as a multifaceted method of testing for frailty [8,23].

Exercise time

Daily exercise time at the individual level was assessed using a self-administered questionnaire for frequency per week (5–7 days, 3–4 days, 1–2 days, and not at all) and exercise time per day. The mean exercise time per day was calculated by multiplying the frequency per week (6, 3.5, 1.5, and 0 times/week) by exercise time per day and dividing that by 7 [24]. The exercise time difference was calculated by subtracting baseline exercise time from follow-up exercise time.

Covariates

Age, sex, BMI, living arrangements, working status, self-rated health, perceived household economic status, smoking, alcohol consumption, social activity, and exercise habits were assessed in the baseline survey. BMI was calculated using height and weight, with a BMI < 18.5 kg/m^2 defined as underweight, 18.5–24.9 kg/m^2 as normal weight, and > 25 kg/m^2 as obesity. BMI was also used in No. 12 of the KCL. Living arrangements were assessed as either living alone or with others. Employment was defined as working for pay. Self-rated health was evaluated using a 4-point Likert scale, and perceived household economic status was assessed using a 5-point Likert scale. Alcohol consumption was assessed as drinker or non-drinker. Social activity was measured at least once a month by active members of a group in the following seven categories: (1) groups related to culture and the arts; (2) groups focused on community development; (3) groups supporting children or older adults; (4) groups for crime

and disaster prevention; (5) groups for nature and environmental conservation; (6) groups promoting lifestyle improvement; (7) other groups. Having exercise habits was defined as "exercising at least twice a week for at least 30 min each time for at least 1 year" [25].

Statistical analysis

Based on group exercise continuity, the participants were divided into four groups (continuers, discontinuers, initiators, and non-initiators). Numerical data are presented as mean (standard deviation) or median (interquartile range), whereas categorical data are presented as number (%). One-way analysis of variance was performed for age; the chi-squared test for nominal scale data, and Kruskal–Wallis test for ordinal scale data and exercise time.

The relationship between the implementation status of group exercises and the incidence of frailty was evaluated using Poisson regression with robust variance [26]. Initially, the univariate Poisson regression analysis (crude model) was performed. Subsequently, the Poisson regression analyses were performed after adjusting for age, sex, BMI, living arrangements, employment status, perceived health status, perceived economic status, smoking status, alcohol consumption, social activity, and exercise habits at baseline (Model 1). In addition, Poisson regression analysis was performed by adding frailty status at baseline to the covariates in Model 1 (Model 2). For sensitivity analyses, we imputed the missing data for group exercise and the

128 covariates, creating 20 complete datasets, excluding individuals who lacked outcome data.
129 Subsequently, we analyzed each dataset and pooled the results. All Poisson regression analyses
130 assessed the relative risk (RR), 95% confidence intervals (CIs), and p-values. To focus on older
131 adults with more serious health conditions, this study is divided into binary outcomes: “frailty"
132 and other conditions such as “robust” and “pre-frail”. To analyze binary outcomes, logistic
133 regression analysis may be used to calculate odds ratios. Nevertheless, evidence suggests if the
134 proportion of the outcome is >10%, an odds ratio will overestimate the RR and lead to incorrect
135 interpretation [27,28]. Therefore, we used Poisson regression analysis. To examine changes in
136 individual exercise times within each group, Wilcoxon signed-rank test was used to compare
137 the baseline and follow-up exercise times. Only the data with both baseline and follow-up
138 measurements were analyzed. All statistical analyses were conducted using IBM SPSS
139 Statistics 29 for Windows (IBM Japan, Tokyo, Japan), with the significance level set at 5%.
140
141 Ethics approval
142 This study was conducted in adherence to the Declaration of Helsinki. This study was approved
143 by the Research Ethics Review Committee of the Graduate School of Health Management,
144 Keio University (Approval No. 2018-10) and the Research Ethics Review Committee of the
145 Graduate School of Health Innovation, Kanagawa University of Human Services (approval no.

Hodai 30-005). Consent to participate in the study was obtained through the presentation of an explanatory statement and request that only those who fully understood and agreed with the statement would voluntarily complete the surveys.

Results

Of the 5,839 participants, 4,102 (response rate: 70.2%) responded to the baseline survey. In the follow-up survey, questionnaires were distributed to 4,024 individuals after excluding 26 who died and 52 who withdrew from the Fujisawa City Association of Senior Citizens Clubs or moved from Fujisawa city. Responses were received from 2,285 individuals (response rate: 56.8%). Of these, older adults who were frail at baseline (n = 391), as well as those with missing data on the KCL (n = 362), group exercise (n = 125), or other covariates (n = 71) in the baseline data, were excluded. Additionally, individuals with missing data on the KCL (n = 21) and group exercise (n = 74) in follow-up data were also excluded. This study included 474, 164, 118, and 485 patients in the continuers, discontinuers, initiators, and non-initiators, respectively (Fig. 1).

Fig. 1: Flowchart of enrollment of participants in this study.

Table 1 presents a summary of baseline characteristics of participants and groups. At baseline,

the mean age (standard deviation) was 77.1 (6.9); of the participants, 54.1% (n=672) were women, 61.2% (n=759) were robust, and 38.8% (n=482) had pre-frailty. Group differences were observed for age, sex, employment, self-rated health, non-drinker status, regular exercise habit, and frailty status.

Table 1: Characteristics of participants at baseline

Table 2 shows the participants' frailty status in 2020. Overall, 249 (20.1%) individuals exhibited newly developed frailty. The incidence of frailty was 13.5% (n=64), 29.9% (n=49), 16.1% (n=19), and 24.1% (n=117) among continuers, discontinuers, initiators, and non-initiators, respectively. There were significant differences in the incidence of frailty between groups (p=<0.001).

Table 2: Participants' frailty status in 2020.

Table 3 presents the results of the Poisson regression with robust variance. In the crude model, discontinuers (RR: 1.96, 95% CI: 1.43–2.69) and non-initiators (RR: 1.65, 95% CI: 1.25–2.17), but not initiators (RR: 1.22, 95% CI: 0.77–1.94), differed significantly from continuers (reference group). In Model 1, discontinuers (RR: 1.79, 95% CI: 1.30–2.47) and non-initiators

(RR: 1.34, 95% CI: 1.02–1.81) differed from continuers, whereas initiators showed no significant difference (RR: 1.04, 95% CI: 0.65–1.67). In Model 2, a model in which frailty status at baseline was added to the adjusted variables of Model 1, discontinuers differed from continuers (RR: 1.70, 95 %CI: 1.26–2.30), whereas initiators (RR: 1.05, 95% CI: 0.68–1.63) and non-initiators (RR: 1.30, 95% CI: 0.99–1.70) showed no significant difference. For the sensitivity analysis, overall, 1511 individuals were included (Supplemental Table 1). In Model 2, discontinuers (RR: 1.73, 95% CI: 1.31–2.29) and non-initiators (RR: 1.34, 95% CI: 1.05–1.71) differed from continuers, whereas initiators showed no significant difference (RR: 1.01, 95% CI: 0.67–1.52). The observed difference between continuers and discontinuers seemed robust to unmeasured variables, including both explanatory variables and covariates. However, the difference between continuers and non-initiators showed different results. The highest missing rate of any variable was for group exercise (8.3%).

Table 3: Poisson regression with robust variance between group-exercise implementation and the incidence of frailty

Exercise time at individual level is presented as the median (interquartile range). Exercise time significantly decreased from 25.7 (12.9–51.7) to 17.1 (6.4–30.0) min/day in discontinuers,

whereas it significantly increased from 19.3 (6.4–41.4) to 20.0 (6.4–47.6) min/day in initiators (Fig. 2). No significant differences were observed between continuers and non-initiators.

Fig. 2: Change in exercise time at baseline and follow-up for each group.

Discussion

In this study, we showed that group-exercise implementation status in 2018 and 2020 was associated with the incidence of frailty in 2020, including the COVID-19 pandemic, and that continued group exercise may prevent the development of frailty. Overall, 249 (20.1%) participants who did not originally have frailty experienced newly developed frailty in 2020, including the COVID-19 pandemic. Even after adjusting for baseline age, sex, BMI, living alone, working, self-rated health, perceived household economic status, smoking, alcohol consumption, social activity, exercise habits, and frailty status, we found that older adults who discontinued group exercise was more prone to frailty than those who continued group exercise. Those who discontinued group exercise showed significantly decreased exercise time during the pandemic than that before the COVID-19 pandemic, whereas those who newly started group exercise significantly increased their exercise time than that before the COVID-19 pandemic.

219 The study participants comprised 45.9% men and 54.1% women. The largest proportion of
220 women were in the discontinuer group (65.2%). Women may be more likely than men to
221 discontinue group exercise under social restrictions. Women live longer than men, but also
222 have higher frailty prevalence than men [29,30]. Therefore, encouraging women to continue group
223 exercise may help to reduce frailty.
224 In a systematic review, before the COVID-19 pandemic, 13.6% (13,678 of 100,313) of older
225 adults (≥ 60 years of age) who did not originally have frailty (robust or prefrailty) experienced
226 frailty during a median follow-up period of 3.0 years (range, 1.0–11.7), and the pooled frailty
227 incidence rate was estimated at 43.4/1,000 person-years [31]. The incidence of frailty in this study
228 was 20.1%. This striking difference could be due to the frailty criteria used and the pandemic.
229 Most previous studies used the Fried Cardiovascular Health Study criteria to define frailty [32].
230 Herein, frailty was defined using the KCL. A previous study in Japan that used the KCL to
231 assess incidence of frailty between January 2020, before the COVID-19 pandemic (recall
232 response), and January 2021, during the COVID-19 pandemic, showed a high incidence of
233 frailty (16.0%) [8]. This study suggested that the incidence of frailty is modified by the
234 combination of living alone and being socially inactive, even though each criterion has a
235 relatively large effect. Similarly, in the present study, although the effect of each criterion was
236 relatively large, group-exercise implementation status was associated with the incidence of

237 frailty during COVID-19, suggesting that continued group exercise may prevent the
238 development of frailty.
239 There was no significant difference in non-initiators compared to the continuers in Model 2.
240 As shown in Figure 2, discontinuers showed a significant decrease in exercise time, while the
241 non-initiators showed no change. The lower incidence of frailty in non-initiators compared to
242 discontinuers may have been because non-initiators had fewer missed opportunities for
243 exercise due to the social restrictions implemented during the pandemic, given that they did
244 not originally engage in group exercise. However, the RR compared to continuers was 1.3, and
245 the results of the sensitivity analyses showed a significant difference. This indicates that non-
246 initiators would tend to become more frail than continuers.
247 Four questions in the KCL assessment are socio-environmental in nature: “Do you go out by
248 bus or train by yourself?,” “Do you sometimes visit your friends?,” “Do you go out at least
249 once a week?,” and “Do you go out less frequently compared to last year?” The responses to
250 these questions may have been strongly influenced by the COVID-19 pandemic. Therefore,
251 those with a KCL score of 8 or higher were categorized as having frailty, referring to Hirose et
252 al.,[33] and we analyzed them with Poisson regression analyses. The results of the analysis
253 remained consistent, even when these items were excluded (Supplemental Table 2). In addition,
254 we compared the baseline and follow-up KCL scores of frail older adults separately for the four

255 socio-environmental questions and the 21 other questions. The results showed differences not
256 only in the four socio-environmental questions but also in the other 21 questions (Supplemental
257 Table 3). Therefore, the results of this study consistently reflect the development of frailty in
258 older adults. Since the classification of COVID-19 as a category 5 event in Japan, social
259 restrictions related to the virus have eased, and group exercises are no longer strongly restricted.
260 Considering the possibility of new infectious diseases and disasters in the future, along with
261 the likelihood that individuals may miss long-term activities due to personal health issues or
262 life events even under normal circumstances, the findings of this study are significant.
263 A previous conceptual model proposed that group exercise reduces the likelihood of developing
264 physical and mental illness by improving social relationships, psychological factors, and
265 physical activity continuation in adults and older individuals [34]. The results of this study
266 revealed that continued group exercise can prevent frailty as well as the risk of physical and
267 mental illnesses. A community-wide intervention study was conducted in Fujisawa City to
268 promote physical activity by incorporating the Japanese physical activity guidelines [35,36]. The
269 intervention provided information, education, and community support around a community
270 center in addition to standard health promotion services. The intervention applied the diffusion
271 of innovation theory [37] and community organization theory [38] to develop intervention-
272 enhancement strategies to promote community support and help older adults initiate and sustain

273 participation in group exercises. They were provided with tools such as original exercise
274 programs with CD/DVD/instructions. [39], held regular information exchange meetings, and
275 provided information and discussed the creation of a mechanism for continuing group exercise
276 [17,40,41]. The results of that study indicated that physical activity had increased significantly at
277 the 5-year follow-up among older adults, as compared with those of 20–64 years of age [24].
278 Physical inactivity and lack of exercise are risk factors for frailty [42], and increasing physical
279 activity is an effective intervention for preventing frailty [43]. Therefore, creating environments
280 and systems that encourage older adults to continue group exercise and physical activity, even
281 in the face of social limitations caused by COVID-19 is important.
282 The change in exercise time for each group showed that older adults who discontinued group
283 exercise without continuing it decreased their exercise time. Exercise time should ideally be
284 maintained without discontinuing group exercise; however, group exercise increases the risk
285 of infections, including COVID-19, due to the gathering of several older adults. It is presumed
286 that continuers continued group exercises by devising ways and places to conduct group
287 exercises. Therefore, if group exercise is to be continued, it must be done in a manner that
288 prevents infection as much as possible. In recent years, with the development of digital
289 technology, the number of older adults accessing the internet has increased [44]. Evidence of the
290 effectiveness of online exercise for older adults is increasing [45], and exercise interventions

using information communication devices and other means may be feasible and acceptable in the older adult population [46,47]. The use of digital technology for older adults may therefore be one option to continue group exercise while maintaining social distance in the future and may be used in conjunction with face-to-face sessions to facilitate continued participation.

This study has some limitations. First, the participants were members of a senior club. The participants belonged to a group and were socially active before the COVID-19 pandemic began. Previous studies indicated that social activity is associated with physical frailty among community-dwelling older adults in Japan [48]. Therefore, different results may have been obtained for older adults who were less socially active than the participants in this study. However, the present study's results could also be interpreted as showing differences even among older adults who are participating in society. Second, this study did not consider the effects of nutritional status [49] and cognitive function [50], which are factors associated with frailty. Third, we only collected data on the time and frequency of exercise at the individual level, whereas the types and intensity of exercise at the individual level were unknown. Fourth, many data points were missing. Assuming the population comprised 3247 of the 4102 respondents at baseline—after excluding the 855 identified as frail—the proportion of participants available for analysis was relatively low at 38.2%. The results from the multiple imputation method, which incorporated 270 individuals with missing data, showed consistent findings:

discontinuers were significantly more likely to be frail compared to continuers. However, when analytic and non-analytic participants were compared, differences in characteristics were noted (Supplemental Table 4). The analyzed participants were a population of older adults who were younger, more likely to be male, and in relatively good health compared to the non-analyzed participants. Therefore, while the results of this study could be adapted to some non-frail older adults, limitations remain while applying the results to the entire population (non-frail older adults in the senior club). Fifth, the study did not consider the possibility that frailty may have led the participants to discontinue group exercise. In this study, we were unable to fully investigate the temporal relationship between exposure factors and the resulting outcomes. Specifically, it is possible that the onset of frailty could lead to the discontinuation of group exercise, raising the possibility of reverse causality. However, the results of this study may contribute to clarifying the causal relationship between frailty and group exercise in future research. Future studies should implement a research design that enables the detailed follow-up and clarification of these temporal relationships.

In conclusion, we identified that group-exercise implementation status in 2018 and 2020 was associated with the incidence of frailty in 2020, including the COVID-19 pandemic, and that continued group-exercise participation may prevent incidence of frailty. Overall, 249 (20.1%)

participants who did not originally have frailty experienced newly developed frailty in 2020, including the COVID-19 pandemic. Those who discontinued initiate group exercise was more prone to frailty than those who continued group exercise participation, even after adjusting for multiple covariates. Those who discontinued group-exercise significantly decreased their exercise time during the pandemic than that before the COVID-19 pandemic, whereas those who newly started group exercise significantly increased their exercise time than that before the COVID-19 pandemic. Frailty can be prevented by creating environments and systems that encourage older adults to implement group exercise even when social restrictions are imposed due to infectious diseases such as COVID-19.

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513

514

515 **Table 1**: Characteristics of participants at baseline

	All (n=1241)	Continuers (n=474)	Discontinuers (n=164)	Initiators (n=118)	Non-initiators (n=485)	*P*
Age, years	77.1 (5.9)	76.5 (5.4)	78.4 (5.6)	76.0 (5.9)	77.5 (6.3)	<0.001
Sex						0.009
Men	569 (45.9%)	232 (48.9%)	57 (34.8%)	49 (41.5%)	231 (47.6%)	
Women	672 (54.1%)	242 (51.1%)	107 (65.2%)	69 (58.5%)	254 (52.4%)	
BMI	22.8 (2.8)	22.7 (2.6)	22.6 (2.8)	23.1 (3.4)	22.9 (2.8)	0.935
Underweight	71 (5.7%)	22 (4.6%)	9 (5.5%)	9 (7.6%)	31 (6.4%)	
Normal	928 (74.8%)	369 (77.8%)	123 (75.0%)	83 (70.3%)	353 (72.8%)	
Obesity	242 (19.5%)	83 (17.5%)	32 (19.5%)	26 (22.0%)	101 (20.8%)	
Living alone	199 (16.0%)	86 (18.1%)	32 (19.5%)	13 (11.0%)	68 (14.0%)	0.082
Working	261 (21.0%)	85 (17.9%)	27 (16.5%)	27 (22.9%)	122 (25.2%)	0.018
Self-rated health						<0.001
Excellent	238 (19.2%)	118 (24.9%)	37 (22.6%)	17 (14.4%)	66 (13.6%)	
Good	898 (72.4%)	331 (69.8%)	116 (70.7%)	90 (76.3%)	361 (74.4%)	
Fair	90 (7.3%)	21 (4.4%)	11 (6.7%)	9 (7.6%)	49 (10.1%)	

Poor	15 (1.2%)	4 (0.8%)	0 (0.0%)	2 (1.7%)	9 (1.9%)	
Perceived household economic status						0.348
	49 (3.9%)	15 (3.2%)	8 (4.9%)	10 (8.5%)	16 (3.3%)	
Excellent						
Good	290 (23.4%)	118 (24.9%)	45 (27.4%)	20 (16.9%)	107 (22.1%)	
Fair	792 (63.8%)	310 (65.4%)	93 (56.7%)	76 (64.4%)	313 (64.5%)	
Poor	91 (7.3%)	29 (6.1%)	15 (9.1%)	11 (9.3%)	36 (7.4%)	
Very poor	19 (1.5%)	2 (0.4%)	3 (1.8%)	1 (0.8%)	13 (2.7%)	
Smoking						0.234
Smoker	60 (4.8%)	19 (4.0%)	3 (1.8%)	7 (5.9%)	31 (6.4%)	
Ex-smoker	147 (11.8%)	65 (13.7%)	16 (9.8%)	11 (9.3%)	55 (11.3%)	
Non-smoker	1034 (83.3%)	390 (82.3%)	145 (88.4%)	100 (84.7%)	399 (82.3%)	
Non-drinker	536 (43.2%)	174 (36.7%)	72 (43.9%)	54 (45.8%)	236 (48.7%)	0.002
Regular exercise	772 (62.2%)	391 (82.5%)	109 (66.5%)	72 (61.0%)	200 (41.2%)	<0.001
Social	904 (72.8%)	370 (78.1%)	122 (74.4%)	91 (77.1%)	321 (66.2%)	<0.001

activity						
Frailty status						0.003
Robust	759 (61.2%)	318 (67.1%)	97 (59.1%)	74 (62.7%)	270 (55.7%)	
Pre-frailty	482 (38.8%)	156 (32.9%)	67 (40.9%)	44 (37.3%)	215 (44.3%)	
Exercise time, min/day	25.7 (6.4–51.4)	40.0 (25.7–75.0)	25.7 (12.9–51.4)	19.3 (6.4–41.4)	6.4 (0–25.7)	<0.001

Abbreviations: BMI, body mass index. Note: Numerical data are presented as mean (standard deviation) or median (interquartile range). Categorical data are presented as number (%). Regular exercise was defined as exercising at least twice a week for at least 30 min each time for at least one year. Frailty status was assessed using the Kihon checklist. Total scores of 0–3 and 4–7 points were considered to indicate “robust” and “pre-frailty,” respectively. Missing data on exercise time: continuers, 13; discontinuers, 5; initiators, 1; and non-initiators, 15.

523

524 **Table 2:** Participants' frailty status in 2020.

	All (n=1241)	Continuers (n=474)	Discontinuers (n=164)	Initiators (n=118)	Non-initiators (n=485)	*P*
Frailty status						<0.001
Robust	497 (40.0%)	222 (46.8%)	51 (31.1%)	54 (45.8%)	170 (35.1%)	
Pre-frailty	495 (39.9%)	188 (39.7%)	64 (39.0%)	45 (38.1%)	198 (40.8%)	
Frailty	249 (20.1%)	64 (13.5%)	49 (29.9%)	19 (16.1%)	117 (24.1%)	

525 Frailty status is presented as number (%). Total scores of 0–3, 4–7, and ≥8 points were

526 considered to indicate robust, pre-frailty, and frailty, respectively.

527

Table 3: Poisson regression with robust variance between group-exercise implementation and the incidence of frailty

	Crude model		Model 1		Model 2	
	RR (95% CI)	*P*	RR (95% CI)	*P*	RR (95% CI)	*P*
Continuers	1.00	reference	1.00	Reference	1.00	reference
Discontinuers	1.96 (1.43–2.69)	<0.001	1.79 (1.30–2.47)	<0.001	1.70 (1.26–2.30)	<0.001
Initiators	1.22 (0.77–1.94)	0.398	1.04 (0.65–1.67)	0.858	1.05 (0.68–1.63)	0.822
Non-initiators	1.65 (1.25–2.17)	<0.001	1.34 (1.02–1.81)	0.035	1.30 (0.99–1.70)	0.058

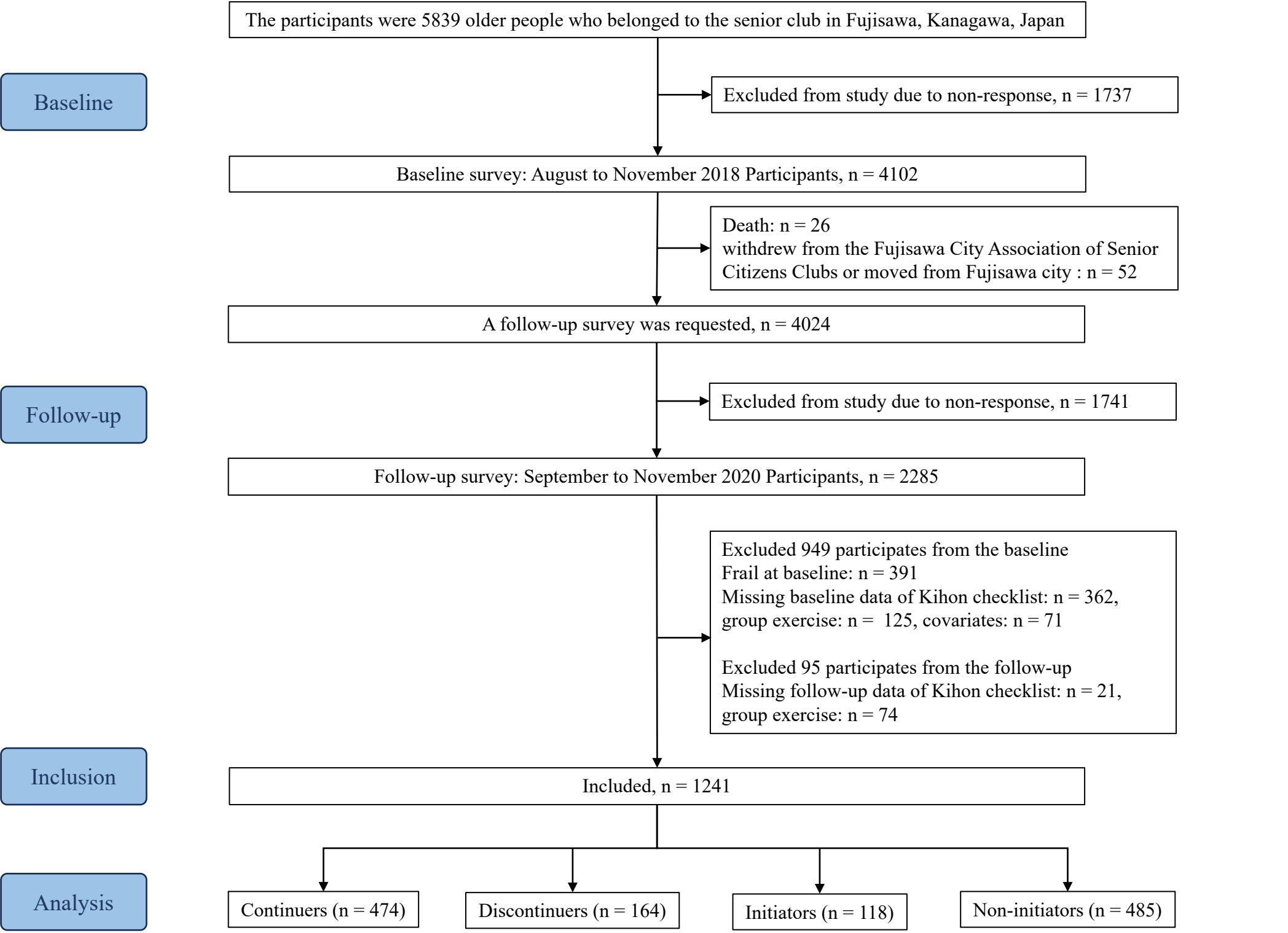
Abbreviations: CI, confidence interval; RR, relative risk. Note: Model 1 was adjusted for age, sex, body mass index, living alone, working, self-rated health, perceived household economic status, smoking, not drinking, and regular exercise at baseline. Model 2 was adjusted for age, sex, body mass index, living alone, working status, self-rated health status, perceived household economic status, smoking status, non-drinking status, social activity status, regular exercise status, and frailty status at baseline.

Figure legends

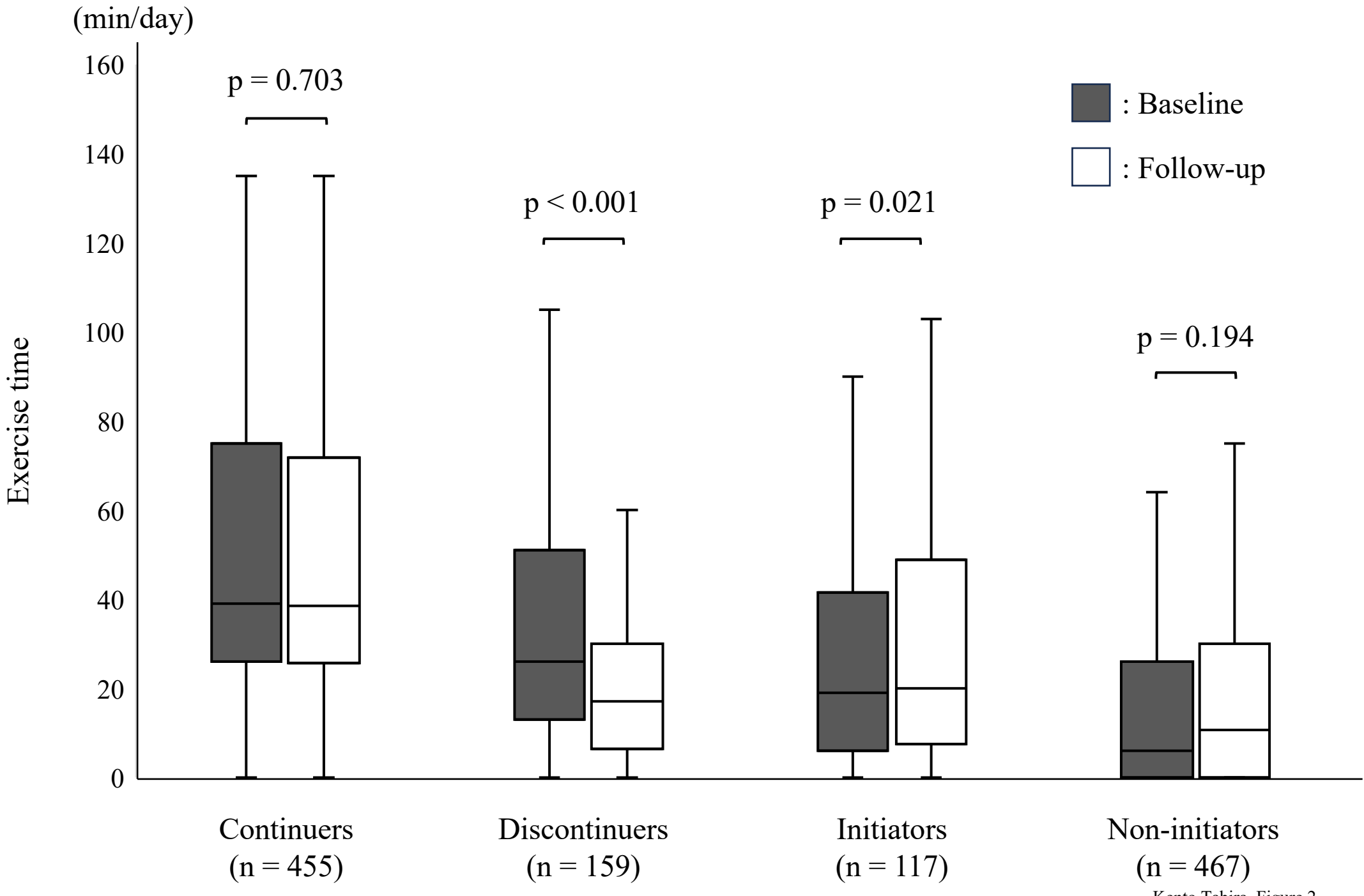
Fig. 1: Flowchart of enrollment of participants in this study.

Fig. 2: Change in exercise time at baseline and follow-up for each group.

Exercise time at the individual level is presented as the median (interquartile range). Differences in exercise time between baseline and follow-up were analyzed by Wilcoxon's signed-rank test. Only the data with both baseline and follow-up measurements were analyzed. Filled black boxes show the baseline data, and unfilled white boxes show the follow-up data. Missing data: continuation group, 19; discontinuation group, 1; initiator group, 5; and non-initiator group, 17.



Kento Tabira, Figure 1



Kento Tabira, Figure 2

Supplemental Table 1: Results from the multiple imputation method

	Crude model		Model 1		Model 2	
	RR (95% CI)	*P*	RR (95% CI)	*P*	RR (95% CI)	*P*
Continuers	1.00	reference	1.00	reference	1.00	reference
Discontinuers	2.11 (1.57–2.85)	<0.001	1.81 (1.35–2.45)	<0.001	1.73 (1.31–2.29)	<0.001
Initiators	1.09 (0.70–1.68)	0.710	0.97 (0.62–1.51)	0.886	1.01 (0.67–1.52)	0.974
Non-initiators	1.74 (1.36–2.23)	<0.001	1.40 (1.08–1.81)	0.010	1.34 (1.05–1.71)	0.019

Abbreviations: CI, confidence interval; RR, relative risk. Note: Frailty status was assessed using the Kihon Checklist. Total scores of 0–3, 4–7, and ≥8 points were considered to indicate robust, pre-frailty, and frailty, respectively. Model 1 was adjusted for age, sex, body mass index, living alone, working, self-rated health, perceived household economic status, smoking, not drinking, social activity, and regular exercise at baseline. Model 2 was adjusted for age, sex, body mass index, living alone, working status, self-rated health status, perceived household economic status, smoking status, non-drinking status, regular exercise status, social activity, and frailty status at baseline.

Supplemental Table 2: The Poisson regression with robust variance between group exercise implementation and frailty incidence excluding socio-environmental items (No. 1, 4, 16, 17)

	Crude model		Model 1		Model 2	
	RR (95% CI)	*P*	RR (95% CI)	*P*	RR (95% CI)	*P*
Continuers	1.00	reference	1.00	reference	1.00	reference
Discontinuers	2.61 (1.62–4.26)	<0.001	1.94 (1.22–3.10)	0.005	1.85 (1.19–2.88)	0.006
Initiators	0.91 (0.41–2.01)	0.810	0.80 (0.35–1.82)	0.597	0.85 (0.39–1.84)	0.682
Non-initiators	1.83 (1.20–2.78)	0.005	1.23 (0.80–1.89)	0.343	1.17 (0.77–1.78)	0.471

Abbreviations: CI, confidence interval; RR, relative risk. Note: Frailty status was assessed using the Kihon Checklist. Total scores of 0–3, 4–7, and ≥8 points were considered to indicate robust, pre-frailty, and frailty, respectively. Model 1 was adjusted for age, sex, body mass index, living alone, working, self-rated health, perceived household economic status, smoking, not drinking, social activity, and regular exercise at baseline. Model 2 was adjusted for age, sex, body mass index, living alone, working status, self-rated health status, perceived household economic status, smoking status, non-drinking status, regular exercise status, social activity, and frailty status at baseline.

Supplemental Table 3: Comparison of baseline and follow-up KCL scores categorized based on socio-environmental questions and other questions

	Socio-environmental questions			Other questions		
	2018	2020	*P*	2018	2020	*P*
All (n=249)	0 (0 - 1)	2 (1 - 3)	<0.001	4 (3 - 6)	7 (7 - 9)	<0.001
Continuers (n=64)	1 (0 - 1)	1 (1 - 2)	<0.001	4 (3 - 6)	7 (7 - 9)	<0.001
Discontinuers (n=49)	0 (0 - 1)	2 (1 - 3)	<0.001	4 (3 - 5.5)	8 (7 - 9.5)	<0.001
Initiators (n=19)	0 (0 - 1)	2 (1 - 3)	<0.001	4 (4 - 5)	6 (7 - 8)	<0.001
Non-initiators (n=117)	0 (0 - 1)	2 (1 - 3)	<0.001	4 (3 - 6)	7 (6 - 9)	<0.001

Note: Frailty status was assessed using the Kihon Checklist. Kihon Checklist scores are shown as median (interquartile range). The analysis was conducted using the Wilcoxon rank-sum test.

Supplemental Table 4. Comparison of analyzed and excluded subjects (n=3247)

	Analytic (n = 1241)	Non-analytic (n = 2006)	*P*
Age, years	77.1 (5.9)	79.3 (6.5)	<0.001 [a]
Sex			<0.001 [b]
Men	569 (45.9%)	726 (37.4%)	
Women	672 (54.1%)	1216 (62.6%)	
BMI	22.8 (2.8)	22.7 (3.1)	0.158 [b]
Underweight	71 (5.7%)	124 (6.7%)	
Normal	928 (74.8%)	1378 (74.0%)	
Obesity	242 (19.5%)	361 (19.4%)	
Living alone	199 (16.0%)	366 (19.3%)	0.023 [b]
Working	261 (21.0%)	407 (21.2%)	0.929 [b]
Self-rated health			<0.001 [c]
Excellent	238 (19.2%)	268 (14.0%)	
Good	898 (72.4%)	1336 (69.9%)	
Fair	90 (7.3%)	236 (12.4%)	
Poor	15 (1.2%)	70 (3.7%)	
Perceived household economic status			<0.001 [c]
Excellent	49 (3.9%)	41 (2.1%)	
Good	290 (23.4%)	174 (9.1%)	
Fair	792 (63.8%)	1283 (67.1%)	
Poor	91 (7.3%)	345 (18.0%)	
Very poor	19 (1.5%)	70 (3.7%)	
Smoking			0.006 [b]
Smoker	60 (4.8%)	95 (5.1%)	
Ex-smoker	147 (11.8%)	157 (8.4%)	
Non-Smoker	1034 (83.3%)	1626 (86.6%)	
Non-drinker	536 (43.2%)	962 (52.3%)	<0.001 [b]
Regular exercise	772 (62.2%)	941 (50.9%)	<0.001 [b]

Social activity	904 (72.8%)	952 (47.9%)	<0.001 [b]
Frailty status			<0.001 [c]
Robust	759 (61.2%)	586 (51.1%)	
Pre-frailty	482 (38.8%)	561 (48.9%)	
Group exercise			<0.001 [b]
Implementation	638 (51.4%)	554 (36.5%)	
Non-implementation	603 (48.6%)	965 (63.5%)	
Exercise time, min/day	25.7 (6.4 – 51.4)	15.0 (0.0 – 45.0)	<0.001 [c]

Abbreviations: BMI, body mass index. Note: Numerical data are presented as means (standard deviation) or median (interquartile range). Categorical data are presented as numbers (%). Regular exercise was defined as exercising at least twice a week for at least 30 min each time for at least 1 year. Frailty status was assessed using the Kihon Checklist. Total scores of 0–3 and 4–7 points were considered to indicate robust and pre-frailty, respectively.

Missing data of analytic: exercise time, 34.

Missing data of non-analytic: age, 78; sex, 64; BMI, 143; Living alone, 109; working status, 84, self-rated health status, 96; Perceived household economic status, 93; smoking status, 128; non-drinking status 167; regular exercise status, 159; social activity status, 17; frailty status, 859; group exercise status, 487; exercise time, 288.

[a] Analysis was conducted using the independent samples t test (2-tailed).

[b] Analysis was conducted using the chi-square test.

[c] Analysis was conducted using the Mann-Whitney U test.