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Original Article

Development of locomotive syndrome in elderly population after COVID-19 outbreak: A population-based cross-sectional study with over 12,000 participants

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ABSTRACT

Background: Restrictions during the coronavirus disease 2019 (COVID-19) pandemic have decreased physical activity levels, which may result in locomotive syndrome. This study evaluated the change in locomotive syndrome prevalence and associated risk factors among an elderly population before and after a coronavirus outbreak.
Methods: This written self-administered cross-sectional survey was conducted in conjunction with the coronavirus disease vaccination program in Habikino City, Japan. Participants who were aged ≥65 years completed the five-question Geriatric Locomotive Function Scale before and during the pandemic. The diagnosis of locomotive syndrome and its stage was based on the Geriatric Locomotive Function Scale score: stage 1 (2–3 points), 2 (4–5 points), and 3 (≥6 points). Data on lifestyle changes, including regular exercise, during the pandemic were collected.
Results: This study included 12,197 participants (36.7% of the city's total elderly residents). The prevalence of locomotive syndrome increased from 41.3% to 47.1% after the outbreak. In total, 765 (6.3% of overall population) and 295 (9.5% of the participants who had stages 1–2 before the pandemic) participants developed locomotive syndrome and stage 3 locomotive syndrome, respectively. The multivariate logistic regression analysis indicated that a decrease in exercise was significantly associated with the onset of locomotive syndrome (all stages) (odds ratio = 2.5, $p < 0.001$) and locomotive syndrome stage 3 (odds ratio = 2.6, $p < 0.001$).
Conclusions: Extrapolation of the study's findings to the entire population of Japan suggests that approximately 2 million elderly individuals might develop locomotive syndrome after the coronavirus outbreak. Additionally, 10% of the participants with mild-moderate locomotive syndrome before the pandemic may develop severe locomotive syndrome after the outbreak. The greatest risk factor for new-onset or worsening locomotive syndrome was a decrease in daily exercise. Thus, there is an urgent need for adequate exercise guidelines during the coronavirus pandemic, especially for the elderly population.

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic has had adverse health and socioeconomic impacts worldwide [1]. While government restrictions such as lockdown and self-isolation have slowed the spread of COVID-19 in local communities, they have negatively affected several aspects of daily life, most notably the level of physical activity [2,3]. For example, a previous study reported that the total physical activity time in the elderly population decreased by 35% after a COVID-19 outbreak [3]. In addition, an investigation conducted by a software company that produced wearable devices for tracking physical activity found a 40% reduction in average step count in most countries after the outbreak [4].

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Locomotive syndrome (LS) is a condition of reduced mobility due to the impairment of locomotive organs [5,6]. LS is classified into three stages according to the degree of severity: stage 1 (LS-1, initial decline in mobility function); stage 2 (LS-2, progressive decline in mobility function); and stage 3 (LS-3, progressive decline in mobility function and hindered social participation) [7]. Although physical tests or the 25-question Geriatric Locomotive Function Scale (GLFS-25) have been considered as essential for the diagnosis of LS, the diagnostic yield and clinical relevance of the 5-question GLFS (GLFS-5) have recently been validated [8,9].

While the prevalence of LS increases secondary to a rapidly aging global population [10], there has been increasing concern that the magnitude and rapidity of this increase may be greater than expected due to the decrease in physical activity during the COVID-19 pandemic. One study found that the prevalence of LS in patients with musculoskeletal disorders increased during the COVID-19 pandemic [11]. However, to date, no studies have investigated the incidence of new-onset LS after a COVID-19 outbreak in elderly populations.

The majority of previous surveys during the COVID-19 pandemic have utilized online questionnaires. However, this method requires that participants access the survey on a website and self-register prior to completing the questionnaire. This may result in major sampling bias if used among elderly individuals, as they may not be familiar with the use of online platforms [3]. Therefore, we used a self-administered, written questionnaire form in the present study. The objective of this population-based cross-sectional survey was to evaluate the change in LS prevalence among the elderly population after a COVID-19 outbreak. We also identified risk factors and characteristics of new-onset LS after the outbreak.

2. Materials and methods

2.1. Survey design

The survey was conducted in conjunction with the COVID-19 vaccination program in Habikino City, Osaka, Japan. The Japanese COVID-19 vaccination strategy dictated that vaccines be provided to the elderly population (aged ≥65 years) on a priority basis; each city established its own vaccination program for their residents. Habikino City where we performed the current study is a mid-sized urban center with an estimated population of 110,106, including 33,191 elderly residents, and a population density of 4100 persons per km^2 [12]. The city is a regional commercial center. Its local economy is primarily based on agriculture and some small industries. Elderly residents in the city received their vaccination at a single center. After obtaining permission from Habikino City and IRB approval from our institution, we invited all elderly residents who received their second vaccination at the center to participate in our survey. Participants who provided informed consent were enrolled in this study. Participants were allowed to withdraw from the study at any time.

2.2. Questionnaire

Participants were instructed to refer to the following two time points when completing the questionnaire: “pre-outbreak” (March to April, 2020) and “current situation” (June to July, 2021).

2.3. General information

The questionnaire collected the following basic demographic and clinical information: age, sex, body height, body weight, and body mass index (BMI). Musculoskeletal symptoms, including back pain (neck pain and/or back pain), joint pain (hip, knee, and/or ankle joint pain), and numbness (upper and/or lower extremity numbness) were evaluated at two time points. In addition, changes in exercise habits (stable, increased, decreased, and no exercise habit) after the COVID-19 outbreak were recorded.

2.4. GLFS-5

The GLFS-5 is a self-administered questionnaire that consists of five items graded on a 5-point scale (0–4 points), for a total possible score of 0–20 points; a higher score indicates a greater LS severity (Table 1) [13,14]. In the current study, participants who scored 2–3, 4–5, and ≥6 points were diagnosed with LS-1, LS-2, and LS-3, respectively [14].

2.5. Statistical analysis

2.5.1. Estimation of new-onset LS and LS-3 prevalence

The prevalence rates of new-onset LS and LS-3 after the COVID-19 outbreak were determined by changes in the distribution of GLFS-5 scores. A score of <2 points at both time points indicated the normal population without LS. The population with new-onset LS was defined as those with a score of <2 before the outbreak and a score of ≥2 after the outbreak. The population with new-onset LS-3 was defined as a score of between 2 and 5 before the outbreak and a score of ≥6 after the outbreak. The population with a score of between 2 and 5 at both time points were defined as those who still had LS-1/2 after the outbreak; this population was demonstrated as LS-1/2 control group and used as the control group to the new-onset LS-3 group.

2.5.2. Risk factors of LS and LS-3 onset after the outbreak

Data on age, sex, height, weight, BMI, and changes in daily exercise habits were extracted. Inter-group comparisons between the normal population and those with new-onset LS, and between the LS-1/2 control group and the new-onset LS-3 group were made with the Mann–Whitney U test for continuous variables and the chi-squared test for categorical variables. A residual analysis was performed as a post-hoc analysis of the chi-squared test. Two multivariate logistic regression models were used to evaluate the relationship of new-onset LS and LS-3 with the following explanatory variables: age, sex, BMI, and changes in regular exercise. Adjusted odds ratios and 95% confidence intervals of the dependent variables were calculated.

2.5.3. Relationship between new-onset LS and musculoskeletal symptoms

The presence/absence of musculoskeletal symptoms at the two time points was compared between the normal population and new-onset LS population, and between the LS-1/2 control group and the new-onset LS-3 group using the chi-squared test and residual analysis.

2.6. Statistical analysis software and level of significance

All analyses were performed using SPSS software (version 23.0; SPSS, Chicago, IL, USA). Statistical significance was set at $p < 0.05$. In the residual analysis, the results were reported as $p < 0.05$ when $|r|$ was >1.96, according to the Haberman method [15].

3. Results

3.1. Number of participants

A total of 15,600 elderly residents received their second vaccination during the examination period. Among them, 12,759 residents agreed to participate in our survey. After survey completion, 562 participants were excluded from the analysis due to missing

Table 1
The GLFS-5 questionnaire items.

Questionnaire item
1. To what extent has it been difficult to go up and down stairs?
2. To what extent has it been difficult to walk briskly?
3. How far can you keep walking without rest?
4. To what extent has it been difficult to carry objects weighing 2 kg?
5. To what extent have load-bearing tasks and housework been difficult?

GLFS-5, five-question Geriatric Locomotive Function Scale.

information: age (n = 107), sex (n = 155), body height/weight (n = 68), changes in exercise habits (n = 157), and GLFS-5 (n = 75). Therefore, a total of 12,197 participants (36.7% of the total elderly residents of Habikino City; response rate, 95.6%) were included in the analysis (Fig. 1).

3.2. Estimation of the prevalence of new-onset LS and LS-3

The distribution of GLFS-5 scores at the two time points showed that the prevalence of LS increased from 41.3% before the outbreak to 47.1% after the outbreak (Table 2). Similarly, the prevalence of LS-1 (15.0%–18.2%), LS-2 (10.9%–11.2%), and LS-3 (15.8%–17.9%) increased after the outbreak. In terms of the individual changes, a total of 765 participants (6.3% of all participants) developed LS from normal condition after the outbreak. Additionally, 296 participants (9.4% of the participants who were with LS-1/2 before the outbreak) developed LS-3 after the outbreak.

3.3. Risk factors of LS onset after the outbreak

Univariate comparisons between the normal population and participants who developed LS indicated significant differences in

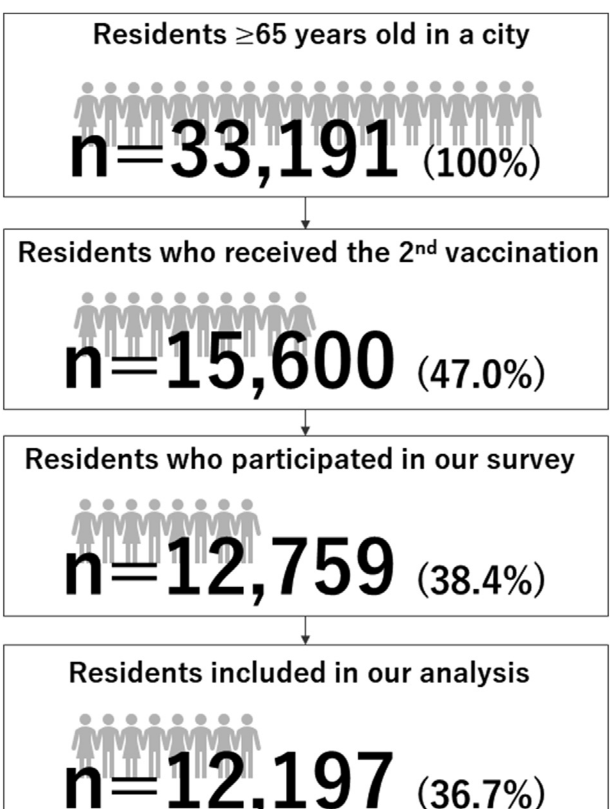

Fig. 1. Flow chart of participant selection.

Table 2
Distribution of GLFS-5 scores before and after the coronavirus disease 2019 outbreak.

Score	LS grade	Pre-outbreak (March 2020)	Post-outbreak (July 2021)
0	Non-LS	5364 (44.0)	4486 (36.8)
1		1748 (14.3)	1969 (16.1)
2	LS-1	1024 (8.4)	1238 (10.2)
3		808 (6.6)	972 (8.0)
4	LS-2	581 (4.8)	701 (5.7)
5		742 (6.1)	667 (5.5)
6	LS-3	333 (2.7)	386 (3.2)
7		245 (2.0)	277 (2.3)
8		173 (1.4)	215 (1.8)
9		132 (1.1)	167 (1.4)
≥10		1047 (8.6)	1119 (9.2)

Numbers in parentheses indicate percentages.
GLFS-5, five-question Geriatric Locomotive Function Scale; LS-1, locomotive syndrome stage 1 (2–3 points); LS-2, locomotive syndrome stage 2 (4–5 points); LS-3, locomotive syndrome stage 3 (≥6 points).

age distribution, sex distribution, and changes in daily exercise habits (Table 3). Residual analysis revealed that the LS group had larger proportions of female and older (aged >75 years) participants, as well as participants who experienced a decrease in exercise habit, compared to the normal population. The multivariate logistic regression analysis indicated that older age, female sex, and a lower level of exercise were significantly associated with the onset of LS after the outbreak (Table 4). The risk of developing LS after the outbreak was 2.4 times higher in individuals aged >75 years than in those aged 65–75 years ($p < 0.001$), 1.2 times higher in women than in men ($p = 0.021$), and 2.5 times higher in individuals who experienced a decrease in exercise habit compared to those who maintained their regular exercise habits ($p < 0.001$). Additionally, the lack of any exercise habits was also a significant risk factor for LS onset ($p < 0.001$).

3.4. Risk factors of LS-3 onset after the outbreak

Univariate comparison between the LS-1/2 control group and the new-onset LS-3 group showed significant differences in age

Table 3
Participant demographics according to whether LS developed after the coronavirus disease 2019 outbreak.

	Normal control	New-onset LS group	p-value
Numbers	6347	765	
Age			<0.001
65–70	2962 (46.7)	212 (27.7)*	
71–75	1949 (30.7)	238 (31.3)	
76–80	997 (15.7)	182 (23.8)*	
81–85	349 (5.5)	94 (12.3) *	
≥86	91 (1.4)	39 (5.1)*	
Sex			<0.001
Male	3355 (52.9)	344 (45.0)*	
Female	2992 (47.1)	421 (55.0)*	
Height (cm)	160.9 ± 8.6	159.1 ± 9.1	<0.001
Weight (kg)	59.0 ± 10.6	58.2 ± 12.0	0.055
BMI	22.7 ± 3.4	22.8 ± 3.5	0.262
Daily exercise			<0.001
Stable	4096 (64.5)	342 (44.7)*	
Increase	169 (2.7)	20 (2.6)	
Decrease	1677 (26.4)	346 (45.2)*	
No habit	405 (6.4)	57 (7.5)	

"Pre Normal–Post Normal" and "Pre Normal–Post LS" indicate the normal population and those with new-onset LS, respectively.
Continuous data are presented as the mean value ± standard deviation. Numbers in parentheses indicate percentages.
#One-way analysis of variance; †chi-squared test; *$p < 0.05$, residual analysis.
BMI, body mass index; LS, locomotive syndrome.

distribution, and changes in daily exercise habits (Table 5). Participants with new-onset LS-3 were more likely to be older, and have a larger decrease in exercise habit compared to the LS-1/2 control group. Multivariate logistic regression analysis indicated that older age, and a decrease in exercise habit were significantly associated with the onset of LS-3 after the outbreak (Table 6). The risk of developing LS-3 was 1.5 times higher in individuals aged >75 years than in those aged 65–75 years ($p = 0.004$), and 2.6 times higher in individuals who had decrease in their exercise habit compared to those who maintained their regular exercise habits ($p < 0.001$). Additionally, the lack of any exercise habits was also a significant risk factor for LS-3 onset ($p = 0.007$).

3.5. Relationship between new-onset LS and musculoskeletal symptoms

The prevalence rates of back pain, joint pain, and numbness at the two time points were significantly higher in participants with new-onset LS than in those in the normal population (Table 7), and in those with new-onset LS-3 than in the LS-1/2 control group (Table 8). Additionally, the ratio of participants who developed back pain after the COVID-19 outbreak was three times higher in the new-onset LS compared to the normal population. Similarly, the number of participants who developed joint pain after the outbreak was five times higher among those with new-onset LS compared to participants in the normal population.

4. Discussion

The main findings of the current survey were as follows: (1) LS prevalence increased from 41% to 47% within approximately 1.5 years after the COVID-19 outbreak; (2) 6.3% of all participants newly developed LS after the pandemic; (3) 9.4% of the participants with LS-1/2 pre-outbreak developed LS-3 after the outbreak; (4) common risk factors of LS and LS-3 onset after the pandemic included older age, and decrease in exercise habit; and (5) back pain and/or joint pain was more prevalent among participants who developed LS or LS-3 after the outbreak.

The standard diagnostic tools for LS are physical examinations (two-step test and stand-up test) and/or the self-reported GLFS-25 [7]. While the use of all three tests may be ideal for the accurate determination of LS prevalence, this is not feasible in large-scale population studies with over 10,000 individuals. Furthermore, the GLFS-25 is relatively complex, as it includes a large number of questions and takes a long time to complete. Indeed, previous studies have reported response rates ranging from 50 to 70%, thus indicating some bias in the results [16]. To address this issue, we used the GLFS-5, which only includes five items and has been previously validated. Kobayashi et al. reported a strong positive correlation between GLFS-5 and GLFS-25 and calculated the cut-off value for each stage of LS [8]. While we acknowledge that the present study only demonstrated the prevalence of "suspected" LS, the high response rate (95.6%) indicated that our results were less affected by selection bias than previous surveys using the GLFS-25.

The prevalence of LS in the present study increased from 41% to 47% within approximately 1.5 years after the COVID-19 outbreak. In a study conducted prior to the COVID-19 outbreak, Yoshimura et al. used the GLSF-25 to determine LS prevalence rates of 59% and 33% in women and men in their 60s, respectively [17]. Taniguchi et al. reported a pre-outbreak LS prevalence rate of 42.1% in a 70–74-year-old cohort and 52.2% in a >75-year-old cohort [18]. As the present study included individuals aged over 65 years, the baseline LS prevalence of 41% before the outbreak (from March to April 2020) was not unexpectedly high.

New-onset LS were observed in 6.3% of the participants after the COVID-19 outbreak. The Japanese government has estimated that there are 36,400,000 elderly individuals aged ≥65 years in Japan [19]. When our results are extrapolated to the entire Japanese population, it is suggested that approximately 2,283,000 and 1,122,000 elderly individuals might developed LS and LS-3, respectively, after the COVID-19 outbreak. The results of the present study suggest that the prevalence of LS, particularly the most severe stage, might be increasing more rapidly than originally expected before the COVID-19 outbreak. These findings could indicate that there will also be a corresponding increase in the number of elderly people requiring nursing care in the near future.

The new-onset of LS and LS-3 was significantly associated with older age, and the development of joint and back pain. These

Table 5
Participant demographics according to whether LS-3 newly developed after the coronavirus disease 2019 outbreak.

	LS-1/2 control group	New-onset LS-3 group	p-value
Numbers	2860	295	
Age			<0.001
65–70	161 (5.6)	11 (3.7)	
71–75	629 (22.0)	50 (16.9)*	
76–80	912 (31.9)	82 (27.8)	
81–85	687 (24.0)	75 (25.4)	
≥86	471 (16.5)	77 (26.1)*	
Sex			0.407
Male	1157 (40.5)	112 (38.0)	
Female	1703 (59.5)	183 (62.0)	
Height (cm)	158.0 ± 8.4	156.8 ± 8.8	0.020
Weight (kg)	58.1 ± 15.8	57.5 ± 11.7	0.525
BMI	23.2 ± 5.2	23.3 ± 3.9	0.667
Daily exercise			<0.001
Stable	1599 (55.9)	106 (35.9)*	
Increased	49 (1.7)	6 (2.0)	
Decreased	877 (30.7)	147 (49.8)*	
No habit	335 (11.7)	36 (12.2)	

Continuous data are presented as the mean value ± standard deviation. Numbers in parentheses indicate percentages.
#One-way analysis of variance; †chi-squared test; *$p < 0.05$, residual analysis.
BMI, body mass index; LS-3, locomotive syndrome stage 3.

Table 4
Risk factors for LS onset after the coronavirus disease 2019 outbreak.

Objective variable: Individuals who developed LS after the outbreak					
Explanatory variables		Reference	aOR	p-value	95% CI
Age	>75	65 to 75	2.43	<0.001	2.05–2.88
Sex	Female	Male	1.20	0.021	1.03–1.41
BMI	<18	18 to 30	1.38	0.063	0.98–1.93
	>30	18 to 30	1.17	0.884	0.14–10.07
Regular exercise	Increase	Stable	1.62	0.068	1.03–2.62
	Decrease	Stable	2.52	<0.001	2.14–3.00
	No habit	Stable	1.84	<0.001	1.36–2.49

aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval.

Table 6
Risk factors for LS-3 onset after the coronavirus disease 2019 outbreak.

Objective variable: Individuals who developed LS-3 after the outbreak					
Explanatory variables		Reference	aOR	p-value	95%CI
Age	>75	65 to 75	1.54	0.004	1.14–2.07
Sex	Female	Male	0.98	0.844	0.76–1.26
BMI	<18	18 to 30	1.24	0.381	0.76–2.03
	>30	18 to 30	1.41	0.747	0.17–11.54
Regular exercise	Increase	Stable	1.89	0.154	0.79–4.51
	Decrease	Stable	2.59	<0.001	1.98–3.37
	No habit	Stable	1.73	0.007	1.16–2.57

aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval; LS-3, locomotive syndrome stage 3.

Table 7
Comparison of musculoskeletal symptoms between participants who developed and did not develop LS after the coronavirus disease 2019 outbreak.

	Normal control (n = 6347)	New-onset LS group (n = 765)	p-value
Back pain			
Pre-pandemic	1039 (16.4)	224 (29.3)	<0.001
Post-pandemic	1100 (17.3)	251 (32.8)	<0.001
Newly emerging	92 (1.4)	34 (4.4)	<0.001
Joint pain			
Pre-pandemic	186 (2.9)	88 (11.5)	<0.001
Post-pandemic	215 (3.4)	108 (14.1)	<0.001
Newly emerging	34 (0.5)	20 (2.6)	<0.001
Numbness			
Pre-pandemic	114 (1.8)	37 (4.8)	<0.001
Post-pandemic	121 (1.9)	44 (5.8)	<0.001
Newly emerging	9 (0.1)	9 (1.2)	<0.001

Numbers in parentheses indicate percentages.
#One-way analysis of variance; †chi-squared test; *$p < 0.05$, residual analysis.
BMI, body mass index; LS, locomotive syndrome.

Table 8
Comparison of musculoskeletal symptoms between participants who developed and did not develop LS-3 after the coronavirus disease 2019 outbreak.

	LS-1/2 control group (n = 2860)	New-onset LS-3 group (n = 295)	p-value
Back pain			
Pre-pandemic	777 (27.2)	109 (36.9)	0.002
Post-pandemic	807 (28.2)	112 (38.0)	0.001
Newly emerging	48 (1.7)	10 (3.4)	<0.001
Joint pain			
Pre-pandemic	313 (10.9)	64 (21.7)	<0.001
Post-pandemic	328 (11.5)	67 (22.7)	<0.001
Newly emerging	19 (0.7)	5 (1.7)	0.067
Numbness			
Pre-pandemic	151 (5.3)	35 (11.9)	<0.001
Post-pandemic	154 (5.4)	41 (13.9)	<0.001
Newly emerging	5 (0.2)	6 (2.0)	<0.001

Numbers in parentheses indicate percentages.
#One-way analysis of variance; †chi-squared test; *$p < 0.05$, residual analysis.
BMI, body mass index; LS-3, locomotive syndrome stage 3.

findings are consistent with those of previous studies. Older age has been previously established as a risk factor for LS [10,16,18,19]. Associations between LS and both low back pain and osteoarthritis of the knee and hip have also been reported [20,21]. Furthermore, we found that a decrease in exercise habit posed the greatest risk for LS and LS-3 onset. Prior studies have suggested that moderate to vigorous physical activity can potentially prevent LS [18,22]. As current evidence indicates that there has been a widespread decrease in exercise and other physical activities after the COVID-19 outbreak [2–4], there is an urgent need for governmental organizations and non-governmental advocacy groups to develop optimal guidelines to ensure that elderly individuals are able to re-establish or maintain daily exercise habits during the COVID-19 pandemic.

Our cross-sectional survey has some limitations. The major limitation was recall bias, as we did not collect data before the pandemic; therefore, the only alternative was to ask participants to report GLFS-5, musculoskeletal symptoms, and exercise habits from the past. Negative emotions, such as fear or anger related to COVID-19, may have affected the results [23]. Additionally, as mentioned previously, the diagnostic tool for LS used in the present study was not officially approved. Furthermore, we did not evaluate improvements in LS after the participants resumed their regular exercise regimens. Therefore, to overcome these limitations, a longitudinal survey that includes pre-pandemic data from a comprehensive sample of the general elderly population would be needed.

Meanwhile, the present study has several strengths. First, the number of included participants comprised more than one-third of all elderly people living in a specific city; this significantly reduced the generalizability bias. Second, self-administered, written questionnaires were used, as opposed to online forms. This enabled the participation of elderly residents who would have had difficulties in accessing and completing online forms; thus, reducing the risk of selection bias. Indeed, we were able to obtain responses from 81.8% of the participants who were asked to participate in the survey, and 12,197 of 12,759 (95.6%) participants were able to complete the questionnaires.

In conclusion, this large-scale cross-sectional survey, which included 37% of all elderly residents a specific city, revealed that 6.3% of all participants developed LS and 9.4% of the participants with mild-moderate LS at pre-outbreak developed severe LS within approximately 1.5 years after the COVID-19 outbreak. Furthermore, our results indicated that a decrease in the exercise habit posed the greatest risk of new-onset LS and LS-3. These findings may be used to facilitate the development of guidelines to ensure optimal daily exercise habits and prevent the onset of LS among elderly individuals during the COVID-19 pandemic.

Ethical statement

This study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants. The study protocol was approved by the institutional review board (IRB) of our institution (approval no: 2021-110). No funds were received in support of this work.

Declaration of competing interest

None.

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