

ORIGINAL ARTICLE

Impact of Habitual Exercise on Locomotive Function of Middle-aged and Elderly Volunteers: A Longitudinal Study

Tomohiro Yamada, MD ^a Yu Yamato, MD, PhD ^{a,b} Tomohiko Hasegawa, MD, PhD ^a
Go Yoshida, MD, PhD ^a Tatsuya Yasuda, MD, PhD ^a Tomohiro Banno, MD, PhD ^a
Hideyuki Arima, MD, PhD ^a Shin Oe, MD, PhD ^{a,b} Hiroki Ushirozako, MD, PhD ^a
Koichiro Ide, MD ^a Yuh Watanabe, MD ^a and Yukihiro Matsuyama, MD, PhD ^a

Objectives: This longitudinal study aimed to evaluate the effect of acquisition of an exercise habit on locomotive dysfunction (LD). **Methods:** The subjects were 121 male and 196 female volunteers aged more than 50 years who attended health checkups in Toei, central Japan, in 2012 and 2014. We divided the subjects into three groups: an acquiring exercise group (Ac-Ex) composed of those who acquired an exercise habit between 2012 and 2014, a non-exercise group (Non-Ex) who did not acquire an exercise habit, and an exercise group (Ex) who already had an exercise habit in 2012. We compared the 25-question Geriatric Locomotive Function Scale (GLFS-25) score among the three groups. **Results:** In men in the Ac-Ex group, the GLFS-25 score improved significantly between 2012 and 2014 ($P=0.046$), and sub-analysis of the GLFS-25 responses showed that fundamental and instrumental activities of daily living (ADL) improved significantly. In women in the Ac-Ex group, the prevalence of radiologically diagnosed knee osteoarthritis was significantly higher ($P=0.027$) than that for the other two groups, and there was no significant improvement in GLFS-25 score over the 2-year period. **Conclusions:** The acquisition of an exercise habit had a positive effect on the locomotive function in men. Orthopedic surgeons must enlighten people on the need for a continuous exercise habit.

Key Words: community-dwelling volunteers; exercise habits; knee osteoarthritis; locomotive dysfunction; 25-question Geriatric Locomotive Function Scale

INTRODUCTION

Japan is a super-aged society, and the elderly population has increased rapidly over recent years. The percentage of individuals aged >65 years was 26.0% in 2014 and is expected to reach 39.9% in 2060.¹⁾ Because the population is aging, nursing care costs have also increased. Currently there are approximately 5 million people in Japan who require nursing care services.²⁾ Consequently, it is important to develop ways to increase the proportion of elderly people who do not require nursing care.

Locomotive syndrome (LS) is a condition present in the

late middle-aged to elderly population who are at high risk of developing systemic musculoskeletal disability.^{3,4)} There are several risk factors that contribute to LS, such as aging, osteoarthritis, osteoporosis, muscle weakness, and lumbar spinal canal stenosis.⁵⁻⁸⁾ Moreover, women have a higher prevalence of LS than men because the levels of testosterone, which promotes muscle development, differ between men and women.⁹⁾ Several recent reports have found that exercise intervention can lead to positive effects on locomotive function.^{10,11)}

However, whether voluntary acquisition of exercise habits can impact locomotive dysfunction among elderly communi-

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^a Department of Orthopedic Surgery, Hamamatsu University School of Medicine, Hamamatsu, Japan

^b Division of Geriatric Musculoskeletal Health, Hamamatsu University School of Medicine, Hamamatsu, Japan

Correspondence: Tomohiro Yamada, MD, 1-20-1 Handayama, Higashi-ku, Hamamatsu-City, Shizuoka 431-3192, Japan, E-mail: cordial27@gmail.com

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ty-dwelling residents and whether sex and other background characteristics play a role in this remain uncertain. Given the gender-related differences in the prevalence of LS, we hypothesized that the influence of acquisition of exercise habits would be different between men and women. The aim of this study was to evaluate the association between the acquisition of exercise habits, locomotive function, and sex in community-dwelling elderly people.

MATERIALS AND METHODS

Subjects

The subjects were community-dwelling volunteers who attended a local government basic health checkup in 2012 and again in 2014. In the town of Toei, this checkup service is held once every 2 years, and the majority of residents attend.^{12–15} Toei is located in Aichi prefecture, in central Japan, and has a population of 3200, of which 49.6% are elderly (more than 65 years old). Toei is in a relatively rural area, and many people work in agricultural and forestry industries. In this study, which started in 2011, we examined LS by investigating motor function, spinal and joint diseases often found in the elderly, and osteoporosis during health examinations. The background characteristics of the subjects, including age, body mass index (BMI), severity of comorbidities, knee or lumbar pain scale, bone mineral density (BMD), knee osteoarthritis, degenerative spondylosis, the 25-question Geriatric Locomotive Function Scale (GLFS-25) score, and physical tests, were assessed.

The severity of comorbidities was assessed using the Charlson comorbidity index (CCI).¹⁶ Pain visual analog scales (VASs) were evaluated for knee pain (scores from 0 to 100, with 100 being the worst pain). The inclusion criteria were: (1) Japanese ethnicity, (2) aged more than 50 years, (3) participation in physical examinations, and (4) the ability to walk independently. Individuals were excluded if they had fractures, had undergone surgery, or had experienced dysfunction of the central or peripheral nervous systems during the 2-year observation period.

This study was approved by the institutional review boards of the authors' institutions (#15–060). Written informed consent was obtained from the subjects who agreed to participate in the study.

Definition of Exercise Habits

The brief questionnaire used to collect information on physical activity behavior in this study had been validated previously.¹⁷ The definition of an exercise habit was as fol-

lows: participation in exercise that causes light sweating for a period of more than 30 min each time, twice per week, for more than a year. Volunteers who already had an exercise habit in 2012 and maintained it during the study period were classified as the exercise group (Ex). Volunteers who acquired an exercise habit during the 2-year study period were classified as the acquiring exercise group (Ac-Ex); all other volunteers were classified as the non-exercise group (Non-Ex). After the health checkup in 2012, we suggested that all subjects who did not have an exercise habit should start exercising.

Assessment of the GLFS-25 Total Score and That for Each Domain

The GLFS-25 is a self-administered but relatively comprehensive questionnaire consisting of 25 items graded on a 5-point scale from no impairment (0 points) to severe impairment (4 points).¹⁸ Based on previous reports, we divided the GLFS-25 scores into five domains, namely pain, fundamental activities of daily living (ADL), instrumental ADL, social activity, and anxiety.¹⁸ We compared the GLFS-25 total scores and the scores for the various domains between the groups. This analysis was adjusted for sex, which is known to be related to LS.¹⁹ The primary outcome of this study was to investigate the changes over a 2-year period in GLFS-25 scores among the three groups: Ex, Non-Ex, and Ac-Ex.

Radiographic Evaluation

BMD was evaluated at the femoral neck using dual-energy X-ray absorptiometry. Lower limb and lumbar radiography were used to diagnose knee osteoarthritis and degenerative spondylosis according to the Kellgren–Lawrence (KL) grade.²⁰ Radiographic knee osteoarthritis and degenerative spondylosis were defined as a KL grade of ≥ 2 .

Physical Tests

We measured the duration of the one-leg standing test performed in the limited space of an outpatient office, with the duration defined as the time for which the subjects, with their eyes open, could balance on one leg. We measured this duration for both the right and left legs, and the results of the leg with the longer duration were used for statistical analysis.²¹ We also assessed long seat type body anteflexion and the functional reach test.²²

Statistical Analysis

Statistical analyses were performed using the SPSS version 25 statistical software package (IBM-SPSS, Chicago, IL,

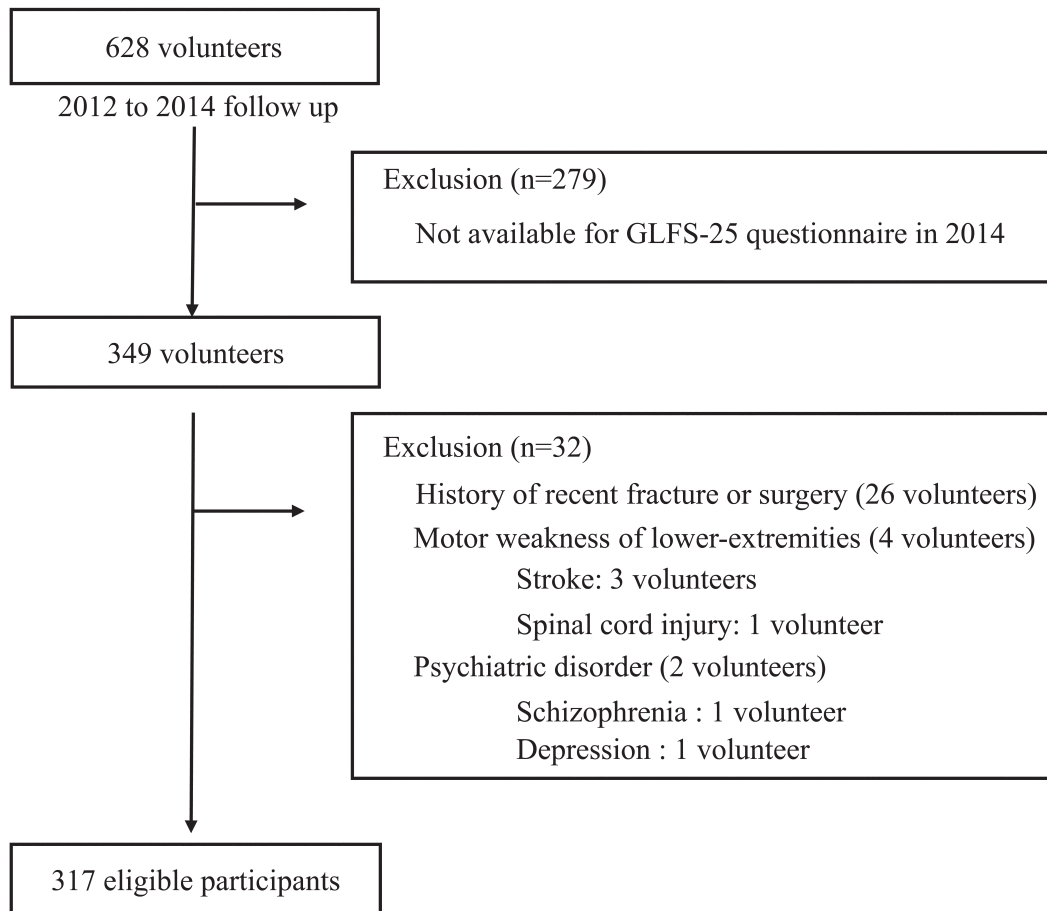


Fig. 1. Flow chart of subject selection and study design.

USA). The background characteristics, GLFS-25 scores, and physical test results among the three groups were assessed using one-way analysis of variance (ANOVA) and χ^2 tests. Post-ANOVA comparisons were made using the Tukey test. The changes in GLFS-25 scores and the physical test results in each group were assessed using paired *t*-tests or Wilcoxon signed rank sum tests. The primary outcome of this study was the change in GLFS-25 scores, and the secondary outcome was the change in physical test results among the three groups. A *P*-value <0.05 was considered to be statistically significant.

RESULTS

A total of 628 volunteers participated in the medical examination in 2012. Of these, we could not obtain follow-up questionnaire data from 279, and those volunteers were excluded. Of the remaining 349 volunteers, 32 were excluded, leaving 317 (121 men, mean age 72.2 years, and 196 women, mean age 71.5 years) for inclusion in this study (Fig. 1). Of

these 317 subjects, 130 were in the Ex group, 147 were in the Non-Ex group, and 40 were in the Ac-Ex group. Table 1 shows a comparison of the eligible volunteers (available to complete questionnaires in 2012 and 2014) and the excluded volunteers. There was no significant difference in background data between volunteers who dropped out and those who were included in the analysis.

Table 2 shows the baseline demographic data in the three groups according to sex. There were significantly more women with knee osteoarthritis in the Ac-Ex group. In men, BMI, CCI, VAS, BMD, knee osteoarthritis, and degenerative spondylosis showed no significant differences among the three groups. Furthermore, Table 3 shows the changes in the GLFS-25 scores and physical test results between 2012 and 2014 in the three groups. The GLFS-25 scores in men in the Ac-Ex group decreased significantly in the 2-year period. In contrast, GLFS-25 scores in women in the Ac-Ex group did not decrease significantly. GLFS-25 scores in the Ex group in both sexes were considered likely to decrease, whereas

Table 1. Comparison of the eligible (n=317) and excluded (n=311) volunteers

Background	Eligible (n=317)	Excluded (n=311)	P values
Age (years)	73.9 ± 7.0	72.4 ± 11.4	0.83
Female (n)	196 (61.8%)	172 (55.4%)	0.23
BMI (kg/m ²)	22.5 ± 2.9	22.4 ± 3.2	0.61
CCI	2.92 ± 0.86	3.02 ± 1.22	0.32
GLFS-25	9.5 ± 10.2	8.3 ± 10.5	0.34

Data are presented as the mean ± standard deviation or n.

BMI: body mass index, CCI: Charlson comorbidity index, GLFS-25: the 25-question Geriatric Locomotive Function Scale.

Table 2. Comparison of baseline (2012) demographic variables among Ex, Non-Ex, and Ac-Ex groups

Background	Men			P values	Women			P values
	Ex (n=42)	Non-Ex (n=64)	Ac-Ex (n=15)		Ex (n=88)	Non-Ex (n=83)	Ac-Ex (n=25)	
Age (years)	73.9 ± 7.0	72.1 ± 7.9	73.5 ± 6.7	0.24	72.8 ± 6.0	70.9 ± 7.8	72.5 ± 7.2	0.15
BMI (kg/m ²)	22.7 ± 2.3	22.6 ± 2.9	23.4 ± 2.6	0.61	22.3 ± 2.8	22.3 ± 3.2	22.1 ± 2.7	0.48
CCI	3.41 ± 1.14	3.40 ± 1.39	3.71 ± 1.49	0.47	3.28 ± 1.27	3.22 ± 1.11	3.18 ± 0.98	0.38
VAS (mm)	21.2 ± 23.3	23.3 ± 20.1	21.4 ± 22.4	0.91	22.5 ± 19.0	26.5 ± 22.3	23.1 ± 21.4	0.58
BMD (%YAM)	78.4 ± 13.1	78.1 ± 13.9	79.1 ± 17	0.95	69.5 ± 11.5	71.6 ± 12.8	71.6 ± 12.9	0.49
Knee osteoarthritis (%)	17 (41)	19 (30)	6 (40)	0.20	52 (59)	45 (54)	19 (76)	0.027*
Degenerative spondylosis (%)	18 (43)	38 (59)	7 (47)	0.062	48 (55)	53 (64)	16 (64)	0.32

Data are presented as the mean ± standard deviation or n.

VAS: visual analog scale, BMD: bone mineral density, YAM: young adult mean.

*Statistically significant (P<0.05).

Table 3. Comparison of GLFS-25 scores and physical test results among Ex, Non-Ex and Ac-Ex groups

	Men			P values	Women			P values
	Ex (n=42)	Non-Ex (n=64)	Ac-Ex (n=15)		Ex (n=88)	Non-Ex (n=83)	Ac-Ex (n=25)	
GLFS-25 score								
Baseline	7.7 ± 10.2	7.1 ± 8.0	7.9 ± 9.8	0.93	8.2 ± 7.3	12.5 ± 12.3	7.9 ± 7.7	0.072
After 2 years	7.3 ± 9.9	9.3 ± 11.9	4.7 ± 4.6	0.28	8.2 ± 7.5	13.1 ± 11.8	7.6 ± 8.3	0.087
P values	0.74	0.030*	0.032*		0.96	0.75	0.89	
One-leg standing test (s)								
Baseline	38.0 ± 22.3	42.3 ± 20.5	47.9 ± 19.0	0.27	41.0 ± 23.6	45.0 ± 22.1	45.0 ± 22.0	0.67
After 2 years	38.0 ± 23.5	37.5 ± 23.4	49.6 ± 19.7	0.29	40.0 ± 22.5	37.4 ± 23.9	46.5 ± 22.9	0.44
P values	0.99	0.079	0.86		0.56	0.059	0.73	
Long seat forward bending (cm)								
Baseline	27.8 ± 9.4	33.5 ± 12.7	30.4 ± 7.9	0.25	34.9 ± 7.1	33.6 ± 7.7	34.0 ± 7.5	0.52
After 2 years	30.0 ± 10.3	32.4 ± 9.5	33.3 ± 7.8	0.46	35.6 ± 8.4	32.6 ± 8.9	34.8 ± 8.6	0.085
P values	0.11	0.52	0.36		0.29	0.11	0.89	
Functional reach test (cm)								
Baseline	37.0 ± 6.6	38.4 ± 6.5	38.2 ± 7.2	0.30	34.4 ± 6.9	35.0 ± 7.1	36.1 ± 5.7	0.79
After 2 years	37.7 ± 7.6	37.1 ± 7.5	38.4 ± 5.2	0.77	35.5 ± 7.7	34.0 ± 7.6	38.7 ± 5.5	0.097
P values	0.49	0.14	0.91		0.22	0.12	0.42	

Data are presented as the mean ± standard deviation.

*Statistically significant (P<0.05).

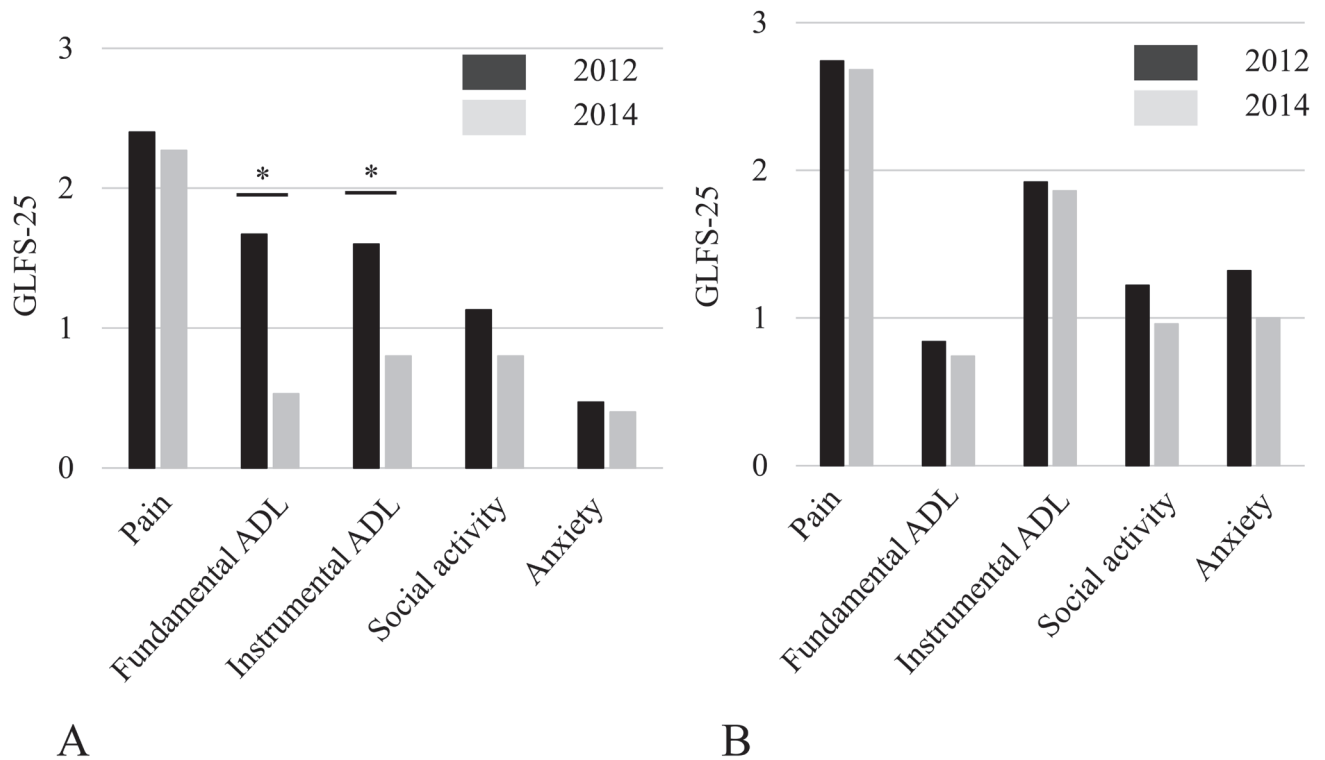


Fig. 2. GLFS-25 scores in the exercise acquiring group for each domain. (A) Comparison between the men's scores in 2012 and 2014. (B) Comparison between women's scores in 2012 and 2014. *Statistically significant ($P < 0.05$).

GLFS-25 scores in Non-Ex men increased significantly. All physical tests in Ac-Ex in both men and women tended to show improvement in scores but did not show significant differences. In contrast, the results of physical tests in the Non-Ex group tended to deteriorate, particularly for the one-leg standing test. **Figure 2** shows the changes in GLFS-25 scores for each domain for men and for women in the Ac-Ex group. In men in the Ac-Ex group, fundamental and instrumental ADL scores in 2014 were significantly lower than those in 2012.

DISCUSSION

In this study, we hypothesized that the impact of newly acquired exercise habits on the GLFS-25 score would be different for men and women among elderly residents in Japan. In support of this hypothesis, GLFS-25 scores were found to have improved significantly in men in the Ac-Ex group (**Table 3**), particularly in the fundamental and instrumental ADL domains. In contrast, the scores did not improve significantly among women.

Acquiring an exercise habit exerted a beneficial effect on a wide range of improved abilities, from sitting-to-standing

transitions to using a bus or train (**Fig. 2A**). It seems possible that these results can be explained by differences in the frequency of resistance training between men and women. Hunter et al. discovered that a resistance training program significantly increased muscular strength and lean body mass.²³⁾ Kwak et al. found that elastic-band resistance training positively influenced older people's balance and gait function.²⁴⁾ Although we recommend further study focusing on the details of exercise habits, our results reinforce the idea that acquiring physical exercise habits prevents older adults from requiring residential aged care.

Another important finding was that there was no significant improvement in GLFS-25 scores following the acquisition of an exercise habit in women (**Fig. 2B, Table 3**). We also revealed that the prevalence of radial knee osteoarthritis in women in the Ac-Ex group was significantly higher than that in the non-Ex group at baseline (**Table 2**). Previous studies have shown that female sex and clinical knee osteoarthritis are specific risk factors for LS.^{25,26)} Ohsawa et al.²⁷⁾ reported that proper care of clinical knee osteoarthritis is needed to prevent progressive walking disability. However, baseline knee VAS did not differ among the three groups, and no differences were found in clinical knee osteoarthritis

prevalence in men in this study. Therefore, a detailed survey relating to the exercise regimens of women who acquire an exercise habit is recommended for future studies.

Several studies have demonstrated a relationship between exercise habits and LS among community-dwelling people.^{28–30} Kota *et al.*³¹ reported that home exercise intervention led to improved physical function in community-dwelling elderly individuals. Maruya *et al.*³² showed the effectiveness of a 6-month exercise program for improving GLFS-25 scores. Similar to these studies, we demonstrated that the Ex group in both sexes maintained their GLFS-25 scores in this study. That finding supported the validity of the hypothesis that maintaining an exercise habit plays an important role in sustaining locomotive function.

The current study has some limitations. First, the number of volunteers was relatively small, and, in particular, the inclusion rate was only 50% (317/628). However, there was no significant difference in backgrounds between volunteers who dropped out and those who were evaluated (**Table 1**). Second, most of the volunteers had previously worked in agriculture and forestry-related occupations, so they probably had some degree of interest in their health. The subjects in this study may differ from people who live in urban areas or in other rural regions. Third, the questionnaires did not elucidate the specific types of exercise undertaken by the subjects. Lim *et al.*³³ reviewed the literature and found evidence that exercise with increased velocity and eccentric strength can improve lower extremity function among the aging population. Therefore, further experimental investigations are needed to establish which types of exercises are effective for improving movement capacity. Regardless of these limitations, the strength of this study was the longitudinal evaluation of the influence of newly-acquired exercise habits on GLFS-25 scores in both men and women.

In conclusion, our findings indicated that middle-aged and elderly men who acquire an exercise habit after a health checkup show significantly improved GLFS-25 scores. Further study into the exercise regimens of both men and women is recommended. Orthopedic surgeons should encourage people to adopt an exercise habit.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

REFERENCE

1. Ministry of Health, Labour and Welfare: Population composition. In: Kosei Rodo Hakusho Heisei 27 Nemban. Ministry of Health, Labour and Welfare, 2015;4–8.
2. Ushio M, Sumitani M, Abe H, Mietani K, Hozumi J, Inoue R, Tsuchida R, Ushida T, Yamada Y: Characteristics of locomotive syndrome in Japanese patients with chronic pain and results of a path analysis confirming the relevance of a vicious cycle involving locomotive syndrome, musculoskeletal pain, and its psychological factors. *Japan Med Assoc J* 2019;2:184–189.
3. Nakamura K: A “super-aged” society and the “locomotive syndrome”. *J Orthop Sci* 2008;13:1–2. DOI:10.1007/s00776-007-1202-6, PMID:18274847
4. Nakamura K: The concept and treatment of locomotive syndrome: its acceptance and spread in Japan. *J Orthop Sci* 2011;16:489–491. DOI:10.1007/s00776-011-0108-5, PMID:21789538
5. Kobayashi K, Imagama S, Ando K, Machino M, Tanaka S, Morozumi M, Kanbara S, Ito S, Inoue T, Ishiguro N, Hasegawa Y: Locomotive syndrome stage 1 predicts significant worsening of future motor performance: The Prospective Yakumo Study. *BioMed Res Int* 2019;2019:1–7. DOI:10.1155/2019/1970645, PMID:31687379
6. Imagama S, Ando K, Kobayashi K, Seki T, Ishizuka S, Machino M, Tanaka S, Morozumi M, Kanbara S, Ito S, Inoue T, Nakashima H, Ishiguro N, Hasegawa Y: Musculoskeletal factors and geriatric syndromes related to the absence of musculoskeletal degenerative disease in elderly people aged over 70 years. *BioMed Res Int* 2019;2019:1–7. DOI:10.1155/2019/7097652, PMID:31886243
7. Kasukawa Y, Miyakoshi N, Hongo M, Ishikawa Y, Kudo D, Kijima H, Kimura R, Ono Y, Takahashi Y, Shimada Y: Lumbar spinal stenosis associated with progression of locomotive syndrome and lower extremity muscle weakness. *Clin Interv Aging* 2019;14:1399–1405. DOI:10.2147/CIA.S201974, PMID:31496667
8. Fink JE, Hackney AC, Matsumoto M, Maekawa T, Horie S: Mobility and biomechanical functions in the aging male: testosterone and the locomotive syndrome. *Aging Male* 2018;0:1–8. DOI:10.1080/13685538.2018.1504914, PMID:30269622

9. Ohtsuki M, Nishimura A, Kato T, Sokejima S, Shibata T, Okada H, Nagao-Nishiwaki R, Sudo A: Relationships between body mass index, lifestyle habits, and locomotive syndrome in young- and middle-aged adults: a cross-sectional survey of workers in Japan. *J Occup Health* 2019;61:311–319. DOI:10.1002/1348-9585.12053, PMID:30982230
10. Hasegawa J, Suzuki H, Yamauchi T: Effect of a lower limb strength training programme on physical activity during the snowy season among community-dwelling elderly individuals. *Ann Hum Biol* 2019;46:323–329. DOI:10.1080/03014460.2019.1641222, PMID:31284765
11. Aoki K, Sakuma M, Endo N: The impact of exercise and vitamin D supplementation on physical function in community-dwelling elderly individuals: a randomized trial. *J Orthop Sci* 2018;23:682–687. DOI:10.1016/j.jos.2018.03.011, PMID:29705177
12. Arima H, Togawa D, Hasegawa T, Yamato Y, Yoshida G, Kobayashi S, Yasuda T, Banno T, Oe S, Mihara Y, Ushirozako H, Hoshino H, Matsuyama Y: Hypertension is related to positive global sagittal alignment: a cross-sectional cohort study. *Asian Spine J* 2019;13:895–903. DOI:10.31616/asj.2018.0308, PMID:31281177
13. Oe S, Togawa D, Yoshida G, Hasegawa T, Yamato Y, Yasuda T, Banno T, Arima H, Mihara Y, Ushirozako H, Matsuyama Y: Effects of mirror placement on sagittal alignment of the spine during acquisition of full-spine standing X-Rays. *Eur Spine J* 2018;27:442–447. DOI:10.1007/s00586-017-5351-9, PMID:29052037
14. Oe S, Togawa D, Nakai K, Yamada T, Arima H, Banno T, Yasuda T, Kobayashi S, Yamato Y, Hasegawa T, Yoshida G, Matsuyama Y: The influence of age and sex on cervical spinal alignment among volunteers aged over 50. *Spine* 2015;40:1487–1494. DOI:10.1097/BRS.0000000000001071, PMID:26208229
15. Yamato Y, Sato Y, Togawa D, Hasegawa T, Yoshida G, Yasuda T, Banno T, Arima H, Oe S, Mihara Y, Ushirozako H, Yamada T, Matsuyama Y: Differences in the geometrical spinal shape in the sagittal plane according to age and magnitude of pelvic incidence in healthy elderly individuals. *J Orthop Sci* 2020;25:557–564. DOI:10.1016/j.jos.2019.07.005, PMID:31378424
16. Gong G, Wan W, Zhang X, Liu Y, Liu X, Yin J: Correlation between the Charlson comorbidity index and skeletal muscle mass/physical performance in hospitalized older people potentially suffering from sarcopenia. *BMC Geriatr* 2019;19:367. DOI:10.1186/s12877-019-1395-5, PMID:31870318
17. Akune T, Muraki S, Oka H, Tanaka S, Kawaguchi H, Nakamura K, Yoshimura N: Exercise habits during middle age are associated with lower prevalence of sarcopenia: the ROAD study. *Osteoporos Int* 2014;25:1081–1088. DOI:10.1007/s00198-013-2550-z, PMID:24146097
18. Seichi A, Hoshino Y, Doi T, Akai M, Tobimatsu Y, Iwaya T: Development of a screening tool for risk of locomotive syndrome in the elderly: the 25-question geriatric locomotive function scale. *J Orthop Sci* 2012;17:163–172. DOI:10.1007/s00776-011-0193-5, PMID:22222445
19. Sasaki E, Ishibashi Y, Tsuda E, Ono A, Yamamoto Y, Inoue R, Takahashi I, Umeda T, Nakaji S: Evaluation of locomotive disability using loco-check: a cross-sectional study in the Japanese general population. *J Orthop Sci* 2013;18:121–129. DOI:10.1007/s00776-012-0329-2, PMID:23114857
20. Kellgren JH: Osteoarthritis in patients and populations. *BMJ* 1961;2:1–6. DOI:10.1136/bmj.2.5243.1, PMID:13752350
21. Michikawa T, Nishiwaki Y, Takebayashi T, Toyama Y: One-leg standing test for elderly populations. *J Orthop Sci* 2009;14:675–685. DOI:10.1007/s00776-009-1371-6, PMID:19802686
22. Duncan PW, Weiner DK, Chandler J, Studenski S: Functional reach: a new clinical measure of balance. *J Gerontol* 1990;45:M192–M197. DOI:10.1093/geronj/45.6.M192, PMID:2229941
23. Hunter GR, Bryan DR, Wetzstein CJ, Zuckerman PA, Bamman MM: Resistance training and intra-abdominal adipose tissue in older men and women. *Med Sci Sports Exerc* 2002;34:1023–1028. DOI:10.1097/00005768-200206000-00019, PMID:12048332
24. Kwak CJ, Kim YL, Lee SM: Effects of elastic-band resistance exercise on balance, mobility and gait function, flexibility and fall efficacy in elderly people. *J Phys Ther Sci* 2016;28:3189–3196. DOI:10.1589/jpts.28.3189, PMID:27942147
25. Takenaka H, Ikemoto T, Suzuki J, Inoue M, Arai YC, Ushida T, Deie M, Kamiya M: Association between trunk muscle strength, lumbar spine bone mineral density, lumbar scoliosis angle, and skeletal muscle volume and locomotive syndrome in elderly individuals: a dual-energy X-ray absorptiometry study. *Spine Surg Relat Res* 2020;4:164–170. DOI:10.22603/ssrr.2019-0083, PMID:32405564

26. Imagama S, Ando K, Kobayashi K, Seki T, Hamada T, Machino M, Ota K, Tanaka S, Morozumi M, Kanbara S, Ito S, Ishiguro N, Hasegawa Y: Impact of comorbidity rates of lumbar spondylosis, knee osteoarthritis, and osteoporosis on physical QOL and risk factors for poor physical QOL in middle-aged and elderly people. *Mod Rheumatol* 2020;30:402–409. DOI:10.1080/14397595.2019.1601839, PMID:30924379
27. Ohsawa T, Yanagisawa S, Shiozawa H, Omodaka T, Saito K, Kitagawa T, Kobayashi H, Tajika T, Yamamoto A, Iizuka Y, Iizuka H, Takagishi K: Relationship between knee osteoarthritis and the locomotive syndrome risk tests: a cross-sectional study. *J Orthop Sci* 2016;21:512–516. DOI:10.1016/j.jos.2016.03.011, PMID:27262920
28. Akahane M, Maeyashiki A, Tanaka Y, Imamura T: The impact of musculoskeletal diseases on the presence of locomotive syndrome. *Mod Rheumatol* 2019;29:151–156. DOI:10.1080/14397595.2018.1452173, PMID:29529893
29. Nishimura A, Ito N, Asanuma K, Akeda K, Ogura T, Sudo A: Do exercise habits during middle age affect locomotive syndrome in old age? *Mod Rheumatol* 2018;28:334–338. DOI:10.1080/14397595.2017.1333670, PMID:28612640
30. Hashizume H, Yoshimura N, Nagata K, Miyazaki N, Ishimoto Y, Nishiyama R, Oka H, Yamada H, Yoshida M: Development and evaluation of a video exercise program for locomotive syndrome in the elderly. *Mod Rheumatol* 2014;24:250–257. DOI:10.3109/14397595.2013.854063, PMID:24593200
31. Kota M, Moriishi M, Hazama A, Hiramoto K: Assessment of the effects of a group intervention program used in home-dwelling elderly individuals to promote home exercise and prevent locomotive syndrome. *J Phys Ther Sci* 2019;31:470–474. DOI:10.1589/jpts.31.470, PMID:31320781
32. Maruya K, Asakawa Y, Ishibashi H, Fujita H, Arai T, Yamaguchi H: Effect of a simple and adherent home exercise program on the physical function of community dwelling adults sixty years of age and older with pre-sarcopenia or sarcopenia. *J Phys Ther Sci* 2016;28:3183–3188. DOI:10.1589/jpts.28.3183, PMID:27942146
33. Lim JY: Therapeutic potential of eccentric exercises for age-related muscle atrophy. *Integr Med Res* 2016;5:176–181. DOI:10.1016/j.imr.2016.06.003, PMID:28462115