〔 **Original Article** 〕

Association of locomotive syndrome with present and past physical activities, and self-reported gait speed: a cross sectional study

Satoshi Yamaguchi[1,2], **Shunji Kishida**[3], **Naoki Yamazaki**[4]

Yasunori Sato[5], **Tomohiro Shirai**[6], **Ryuichiro Akagi**[2]

Takahisa Sasho[2,7], **Seiji Ohtori**[2] **and Kazuhisa Takahashi**[2]

[1] Collage of Liberal Arts and Sciences, Chiba University, Chiba 263-8522.
[2] Department of Orthopaedic Surgery, Graduate School of Medical and Pharmaceutical Sciences, Chiba University, Chiba 260-8670.
[3] Department of Orthopaedic Surgery, Seirei Sakura Citizen Hospital, Sakura 285-8765.
[4] Chiba Foundation for Health Promotion & Disease Prevention, Chiba 261-0002.
[5] Chiba University Hospital Clinical Research Center, Chiba 260-8677.
[6] Section of Physical Therapy, Seirei Sakura Citizen Hospital, Sakura 285-8765.
[7] Center for Preventive Medical Sciences, Chiba University, Chiba 260-0856.

Abstract

The purpose of this study was to clarify the association of locomotive syndrome with present and past physical activities, as well as gait speed. Subjects were recruited from the participants of the specific health checkups in Oamishirasato City. The presence of locomotive syndrome was assessed using the stand-up test, two-step test, and 25-question geriatric locomotive function scale. Present physical activity was measured using the International Physical Activity Questionnaire. Questionnaires were also used to assess past physical activity and usual gait speed. The association of each locomotive syndrome risk test with the physical activities and gait speed was examined using univariate analysis and multiple logistic regression analysis. A total of 172 subjects with a mean age of 67.5 years were enrolled. Sixty-nine（40%）and 13（8%）subjects were classified as having stage 1 and 2 locomotive syndrome, respectively. Among the four groups classified by physical activity level, the proportions of subjects with positive stand-up test were higher in the groups of lowest and highest physical activity（$P = 0.048$）. Faster gait speed was a significant predictor of the negative two-step test（$P = 0.08$）, negative 25-question geriatric locomotive function scale（$P < 0.001$）, and absence of locomotive syndrome（$P = 0.002$）. The associations remained significant in the multiple regression analysis, after adjusting for age, sex, and body mass index. In conclusion, present physical activity was associated with the stand-up test, whereas self-reported usual gait speed was associated with the two-step test and 25-question geriatric locomotive function scale.

Key words: Locomotive syndrome, Physical activity, Gait speed

Address correspondence to Dr. Satoshi Yamaguchi.
Collage of Liberal Arts and Sciences, Chiba University,
133 Yahoicho, Inage-ku, Chiba-shi, Chiba 263-8522, Japan.
Phone: +81-43-226-2117. Fax:+81-43-226-2116.
E-mail: y-satoshi@faculty.chiba-u.jp

Ⅰ. Introduction

Locomotive syndrome（LS）is a condition in which mobility functions such as sit-to-stand or gait are reduced due to locomotive organ impairment［1］. Maintenance of mobility function is the foundation for increasing disability-free life expectancy in Japan, a super-aged society［2］. Identifying modifiable factors that are related to LS is clinically important to prevent the occurrence and progression of LS. Various factors including musculoskeletal pain, back and leg muscle strength, waist circumference, cardiometabolic disorders, and depression have been reported［3-6］.

Being physically active is one of the most important and modifiable factors for healthy aging, since it can lower the risk of many types of diseases and disability, including diabetes, cardiovascular diseases, some forms of cancer, depression, and osteoporosis［7］. In particular, studies have shown that greater physical activity （PA）in daily living is associated with higher physical function and higher activity of daily living（ADL）levels［8］. Moreover, high levels of PA during midlife reduced the risk of occurrence and progression of ADL disability in later life［8,9］. Among several types of instruments available for assessing PA, questionnaires are the most widely used tools［10］. They represent the easiest and least expensive way to collect data from a large number of people in a short time. Although recall and misclassification bias are potential causes of measurement error, present and past PA can be reliably estimated using questionnaires［10］.

In addition to PA, usual gait speed is another important factor that is associated with healthy aging. Slow gait speed is one of the most powerful predictors of ADL disability［11］, as well as the predictors of fall, hospitalization, and mortality［12］. Furthermore, gait speed could be modifiable, and can be a means of intervention to improve physical function［13,14］. While gait speed is generally assessed by measuring the time required to walk a certain distance, self-reported estimation of usual gait speed is also available［15］.

The risk of LS is assessed using the two physical function tests and the questionnaire: the stand-up test, two-step test, and the 25-question geriatric locomotive function scale（GLFS-25）which mainly evaluates limitation in ADL, as well as bodily pain, social function, and mental status［1］. Therefore, one could assume that LS is associated with PA and usual gait speed. However, these associations, with the LS risk tests as variables, have not been well-studied［16］. Clarifying these associations is important, since PA and gait speed in daily living could be modifiable, increasing these factors are recommended by the Ministry of Health, Labour and Welfare for health promotion［17］. The purpose of this study was to assess the association of LS with the present and past PA, as well as usual gait speed, which were estimated using questionnaires.

Ⅱ. Material and Methods

Subject recruitment

Subjects were recruited from the participants of the specific health checkups in Oamishirasato City, Chiba Prefecture, Japan in 2016. The specific health checkups are provided to the National Health Insurance subscribers aged 40 to 74 years by the local government, and primarily focus on lifestyle-related diseases, including metabolic syndrome. The population of Oamishirasato City was 50365 in 2016, with 14316 （28%）residents aged 65 years or more. Five percent of the workers engaged in primary industry, while 21% and 68% engaged in secondary and tertiary industries, respectively. Subjects were recruited at the site of the checkups over a four-day period. The inclusion criteria were as follows, 1）age between 40 and 74 years; 2）ability to walk independently; 3）ability to answer the questionnaires described in the methods; and 4）informed consent. This study was approved by the Institutional Review Board of Graduate School of Medical and Pharmaceutical Sciences, Chiba University （No. 1966）, and all subjects provided written consent.

Subject characteristics

Subject characteristics, including sex, age, height, weight, and body mass index, were recorded. Subjects answered the questionnaire on the presence of chronic

musculoskeletal pain, including neck, shoulder, elbow/wrist, back, lumbar, hip, knee, and foot/ankle, persisting for 3 months or longer, which is potentially associated with LS[5]. The number of painful locations was recorded. The presence of metabolic syndrome was also assessed.

Assessment of LS

LS was assessed by using the short test battery proposed by the Japanese Orthopaedic Association: The stand-up test; two-step test; and GLFS-25[18].

Stand-up test

The subjects were asked to stand up with a single leg or both legs from stools of different height (40, 30, 20, and 10 cm) from the sitting position. The grading of difficulty is as follows; standing with both legs from the 40 (easiest), 30, 20 and 10 cm stools, followed by standing with a single leg from 40, 30, 20 and 10 cm stools (most difficult). The test result was expressed as the minimum height of the stool from which the subject was able to stand.

Two-step test

The subjects stood on both feet. They were told to take two steps, stepping as far as possible while not losing balance, and then align their feet. The two-step score was calculated with the length of two steps divided by the subject's height, and higher scores indicated higher physical function. The trials were performed twice, and the higher value was recorded. One of three certified physical therapists, experienced in the tests, assisted with each set of two functional tests to ensure standardization and safety of the procedure.

The GLFS-25

The GLFS-25 is a self-administered questionnaire consisting of 25 questions regarding the past month[19]. The questionnaire includes 16 questions for ADL, four questions for pain, three questions for social functions, and two questions for mental health status. Each item was rated on a five-point scale from 0 (no impairment) to 4 (severe impairment). The sum of all scores was used for analysis.

The presence of LS was determined using the clinical decision limits proposed by the Japanese Orthopaedic Association[16]. Subjects were classified as having stage 1 LS if one of three conditions was met: Difficulty in single-leg standing from a 40 cm height in the stand-up test (either leg); two-step test ＜1.3; or GLFS-25 score ≧7. Subjects were classified as having stage 2 LS if one of three conditions was met: Difficulty in standing with both legs from a 20 cm height in the stand-up test; two-step test ＜1.1; or GLFS-25 score ≧16.

Assessment of physical activity

Present physical activity

Present PA was estimated using the short version of the International Physical Activity Questionnaire [20]. It is a validated questionnaire, and consists of nine questions regarding the time spent in vigorous- and moderate-intensity activities, walking, and sedentary activity in a usual week. In this study, the sum of vigorous (8 metabolic equivalents, Mets), moderate (4 Mets), and walking (3.3 Mets) activities was calculated as Met*hour/week.

Past physical activity

Past PA was estimated by using the Lifetime Physical Activity Questionnaire[21], which was designed to assess the duration, frequency, and intensity of lifetime recreational and household activities. The Lifetime Physical Activity Questionnaire was originally developed as a self-administered questionnaire, and the reproducibility was confirmed among well-educated women aged between 39 and 65 years. Because the subjects in this study were older than the self-administering group[21], five trained nurses helped them complete the questionnaire. Two other amendments were necessary: the addition of the age period of 66-74 years to the original four prior age periods (12 to 21 years, 22-34, 35-50, and 51-65 years) assessed by the questionnaire, and the inclusion of the occupation questionnaire, a component of the Lifetime Overall Physical Activity Questionnaire[22].

We obtained the Met value of each activity from the Compendium of Physical Activities[23]. Activities of 3 Mets or more were selected as vigorous or moderate activities[8]. Each activity's Met value was multiplied by the reported number of hour/week, fraction of month/ year, and fraction of years lived in each age category, and the mean Met*hour/week was calculated. The total value of the recreational, household, and occupational activities was used for analysis.

Self-reported usual gait speed

Subjects answered the following question: "Compared to the usual walking speed of people of your age, do you think that you usually walk faster[15]?" The answers to be provided were either "yes" or "no."

Statistics

The subject characteristics were expressed as the means and standard deviations for the values that followed normal distribution, and expressed as the median and 25th and 75th percentiles for the values that had non-normal distribution. The results of the LS risk tests were used to classify subjects into three groups according to the criteria for stage 1 and stage 2 LS[16]. Then, subjects with stage 1 and stage 2 LS were combined into one group for statistical analysis, because the number of subjects in stage 2 was small. Using present and past PA, subjects were divided into four groups in the order of the lowest PA (group 1) to the highest PA (group 4) to investigate the possible U-shaped relationship between LS and PA[17]. The cutoff values of 0, 10, and 60 Mets*hour/week were used to classify present PA based on the previous work [17]; 25th, 50th, and 75th percentile values were used for the past PA. The associations of the presence of LS and each LS risk test with PA levels and gait speed were assessed using the chi-square tests, followed by residual analyses as post-hoc comparisons. The associations were further assessed using multiple logistic regression analysis. Each LS risk test result was entered as the objective variable, and PA levels and usual gait speed were entered as the explanation variables, after adjusting for age, sex, and body mass index. The PA levels and

gait speed were also mutually adjusted. Statistical significance was set at $P < 0.05$.

Ⅲ. Results

A total of 172 subjects (122 women and 50 men) participated in this study (Table 1). The target age of the specific health checkup is between 45 and 74 years; the mean age of the subjects in this study was relatively high at 67.5 years (Table 1). Sixty-nine (40%) and 13 (8%) subjects were classified as having stage 1 and 2 LS, respectively (Table 1). The details of subject characteristics are shown in Table 1.

The present PA and stand-up test had a U-shaped relationship, in which the proportions of subjects who were unable to stand from a 40 cm height were higher in group 1 (lowest PA) and 4 (highest PA) than in groups 2 and 3 (moderate PA) ($P = 0.048$, Table 2). The post-hoc residual analysis showed that the proportion of positive test results was significantly higher in group 4 than in group 2 ($P = 0.04$). However, the significance of the association disappeared in the multiple logistic regression analysis ($P = 0.07$, Table 2). Regarding the GLFS-25, no clear association with the present PA was found. The present PA and the two-step test, and presence of LS appeared to have a U-shaped correlation ($P = 0.45$ and $P = 0.19$, Table 2) similar to that between the present PA and stand-up test.

There was also a U-shaped relationship between the past PA and stand-up test: the proportion of subjects with a positive test was higher in groups 1 and 4 than in groups 2 and 3. However, the relationship did not reach statistical significance ($P = 0.25$, Table 3). For the other LS risk tests, the proportions of positive test results were relatively consistent among the four groups of different PA levels (Table 3).

Self-reported usual gait speed was significantly associated with the two-step test. In subjects who reported faster gait speed, 16% had two-step test score of < 1.3, while 34% of subjects not reporting faster gait speed had a score of < 1.3 ($P = 0.008$, Table 4). Gait speed and the GLFS-25 ($P < 0.001$, Table 4), as well as the presence of LS ($P = 0.002$, Table 4), had similar

Table 1　Subject characteristics（n＝172）

Sex	Woman	122
	Man	50
Age（year）		67.5 ± 5.6*
Height（cm）		157.3 ± 7.6*
Weight（kg）		55.0 ± 9.3*
Body mass index（kg/m^2）		22.2 ± 3.0*
Metabolic syndrome	−	151
	+	21
Musculoskeletal pain	0	98
	1	38
	2≦	36
Present physical activity（Mets*hour/week）		13.3（3.3, 32.3）**
Past physical activity（Mets*hour/week）		58.5（35.6, 105.2）**
Gait speed faster than average	−	83
	+	89
Stand-up test	Single-leg 40cm≦	110
	Single-leg 40cm＞, double-leg 20cm≦	57
	Double-leg 20cm＞	5
Two-step test	≧1.3	130
	1.1≦, ＜1.3	38
	＜1.1	4
GLFS-25	＜7	137
	8-15	25
	≧16	10
LS	None	90
	Stage 1	69
	Stage 2	13

Single-leg 40cm, difficulty with a single leg from a 40 cm height（either leg）; *Double-leg 20cm*, difficulty with both legs from a 20 cm height; *LS*, locomotive syndrome; *GLFS*, geriatric locomotive function scale.
　*Mean ± standard deviation.
**Median（25th and 75th percentile values）.

Table 2　Association between present physical activity and LS risk tests（Chi-square test）

LS risk test		Present physical activity				P value
		1（n＝32）	2（n＝44）	3（n＝71）	4（n＝25）	
Stand-up test, single-leg 40cm＞	+	14（44%）	11（27%）	23（32%）	14（56%）	0.048
	−	18	33	48	11	
Two-step test＜1.3	+	10（31%）	8（19%）	16（23%）	8（32%）	0.45
	−	22	36	55	17	
GLFS-25≧7	+	10（31%）	7（17%）	15（21%）	3（12%）	0.26
	−	22	37	56	22	
LS stage 1 or 2	+	19（59%）	16（39%）	33（46%）	14（56%）	0.19
	−	13	28	38	11	

Single-leg 40cm, difficulty with a single leg from a 40 cm height（either leg）; *LS*, locomotive syndrome; *GLFS*, geriatric locomotive function scale. Percent values in the brackets are the proportion of positive test results.

Table 3   Association between past physical activity and LS risk tests （Chi-square test）

LS risk test		Past physical activity				P value
		1 （n＝43）	2 （n＝43）	3 （n＝43）	4 （n＝43）	
Stand-up test, single-leg 40cm＞	＋	19 （44%）	11 （26%）	14 （33%）	18 （42%）	0.25
	－	24	32	29	25	
Two-step test＜1.3	＋	9 （21%）	10 （23%）	11 （26%）	12 （28%）	0.89
	－	34	33	32	31	
GLFS-25≧7	＋	7 （16%）	11 （26%）	8 （19%）	9 （21%）	0.74
	－	36	32	35	34	
LS stage 1 or 2	＋	22 （51%）	18 （42%）	20 （47%）	22 （51%）	0.80
	－	21	25	23	21	

Single-leg 40cm, difficulty with a single leg from a 40 cm height （either leg）; *LS*, locomotive syndrome; *GLFS*, geriatric locomotive function scale. Percent values in the brackets are the proportion of positive test results.

Table 4   Association between self-reported gait speed and LS risk tests （Chi-square test）

LS risk test		Gait speed faster		P value
		＋ （n＝89）	－ （n＝83）	
Stand-up test, single-leg 40cm＞	＋	26 （29%）	36 （43%）	0.06
	－	63	47	
Two-step test＜1.3	＋	14 （16%）	28 （34%）	0.008
	－	75	55	
GLFS-25≧7	＋	9 （10%）	26 （31%）	＜0.001
	－	80	57	
LS stage 1 or 2	＋	32 （36%）	50 （60%）	0.002
	－	57	33	

Single-leg 40cm, difficulty with a single leg from a 40 cm height （either leg）; *LS*, locomotive syndrome; *GLFS*, geriatric locomotive function scale. Percent values in the brackets are the proportion of positive test results.

Table 5   Multiple logistic regression analysis for the association between the faster gait speed and LS risk tests

LS risk test	Odds ratio （95% confidentinterval）	P value
Stand-up test, single-leg 40cm＞	0.48 （0.23－0.97）	0.04
Two-step test＜1.3	0.35 （0.16－0.75）	0.006
GLFS-25≧7	0.26 （0.10－0.60）	0.002
LS stage 1 or 2	0.35 （0.18－0.68）	0.002

Adjusted for age, sex, body mass index, present physical activity, and past physical activity. The reference was the answer "no" to the question. *Single-leg 40cm*, difficulty with a single leg from a 40 cm height （either leg）; *LS*, locomotive syndrome; *GLFS*, geriatric locomotive function scale.

associations, and the subjects with faster gait speed had a lower risk of positive LS risk test. The associations remained significant in the multiple regression analysis, indicating that these were independent of age, sex, body mass index, and PA （Table 5）. The odds ratios for the protective effect of faster gait speed ranged from 0.26 to 0.48 （Table 5）.

Ⅳ. Discussion

We showed that the present PA and the stand-up test appeared to have a U-shaped relationship, in which the risk of positive stand-up test was higher in the groups with the lowest and highest PA than in the groups with moderate PA. No clear relationship was found between the past PA and the LS risk tests. The self-reported gait

speed was associated with the two-step test and GLFS-25 test scores, as well as the presence of LS.

The present PA, measured using the International Physical Activity Questionnaire, was associated with the stand-up test, although the statistical significance was found only in the univariate analysis. Given the significant association between the Questionnaire and quadriceps strength[24], and the association between quadriceps strength and the stand-up test[25], the observed relationship is reasonable. However, it was not a linear relationship: The subjects in the lowest and highest PA groups appeared to have a greater risk of positive stand-up tests than the subjects in moderate PA groups. Similar U-shaped correlations have been reported between PA and lower back pain[26], and between PA and overall health outcomes including mortality, lifestyle-related disease, cancer, and dementia [17]. Taken together, our study and previous studies [17,26] show that both too little and too much PA may be harmful for successful aging. The median PA of the subjects in group 2（present PA more than 0 Mets*hour/week, less than 10 Mets*hour/week）, where the risk of positive stand-up test was lowest, was 5.0 Mets*hour/week. This value seems lower than we expected. It may be because the short version of International Physical Activity Questionnaire tends to underestimate the amount of PA, and is not appropriate to measure the accurate Met value[20]. Using a more accurate method, such as accelerometers, would be necessary to determine the appropriate amount of PA to prevent LS.

The risks predicted by the two-step test and GLFS-25 were similar among the four groups of different present PA levels. Our result contradicts previous meta-analyses that have shown significant association between physical function, ADL disability and the PA[8,9]. One possible explanation for the lack of association is that the short version of International Physical Activity Questionnaire quantifies the amount of PA, and does not specify the type of activity. Several studies have shown that the effect of PA is dependent on its type. While leisure-time PA had a protective effect on mobility and independent aging, occupational physical activity was detrimental[27]. We measured the overall PA because

it is recommended to increase PA, not only through exercise, but also in daily life[17]. However, leisure-time PA, or exercise, may be needed to prevent LS, and further research should focus on the association between LS and the type of PA.

We assessed the past vigorous and moderate PA （between 12 years of age and the current age）, and did not find a clear association with LS. Longitudinal and cross-sectional studies have shown that exercise habits in midlife and late adulthood predict ADL disability, sarcopenia, and functional decline（gait speed and one-leg standing time）about 20 years later [28,29]. Regarding the effect of exercise in earlier life, participating in sport clubs in their school years had little effect on the physical fitness and walking ability（ability to walk for an hour）in people over 65 years of age（Ministry of Education, Culture, Sports, Science and Technology: Results of the FY2015 Survey on Physical Fitness and Motor Abilities, http://www.mext.go.jp/component/english/__icsFiles/afieldfile/2017/01/25/1381545_003.pdf）. The differences in evaluation methods and the interval between the baseline and outcome assessments might have caused the discrepancy between previous studies and ours. For example, it may not be the overall PA, but leisure-time PA（exercise）, that matters to prevent LS as mentioned above.

This study showed that faster self-reported gait speed was associated with reduced risk of LS. Our results agree with those of Yoshimura et al.[16] who found that the indices of the LS risk tests in both stages 1 and 2 were significantly and independently associated with slow gait speed. Our results and those of Yoshimura et al.[16] are as expected, because the LS risk tests were developed to assess locomotive function, which includes walking ability. Of interest is the implication that walking faster might be a means of training to prevent and slow down the progression of LS. Brisk walking for exercise has been recommended to reduce the risk of functional limitation[8]. Furthermore, the physical activity guidelines, published by the Ministry of Health, Labour and Welfare, Japan, also recommend incorporating fast walking in daily life[17]. Although

single-leg standing and squatting are the standard of locomotion training[1], walking could be an attractive option. Since this is a cross-sectional study, the cause-effect relationship between gait speed and LS was not clarified, further research should focus on whether increasing usual gait speed can prevent LS.

This study has a number of limitations. First, the number of subjects was relatively small, and was determined based on availability. Clearly, the results of this study should be confirmed in large-scale cohort studies. Second, only people who were willing to participate were included in this study. Thus, there could have been a selection bias towards people with higher health consciousness. Third, this study was conducted in Oamishirasato City, where about 70% of people were engaged in tertiary industry. The prevalence of LS is different depending on the region, and thus the results of this study may not be extrapolated to other regions. Again, large-scale cohort studies with random sampling and multiple areas are necessary. Fourth, as mentioned in the introduction, PA was estimated using the self-reported questionnaires, which introduce recall and misclassification bias. As mentioned above, the short version of the International Physical Activity Questionnaire tends to underestimate PA[20]. Indeed, as many as 104 out of 172 subjects reported no vigorous and moderate activities for the present PA. Fifth, while we adjusted for age, sex, body mass index, other potential factors, such as cognitive function, diet, comorbidities, and socioeconomic status, were not assessed. These factors should be taken into account to clarify the independent associations in future studies.

In conclusion, the present PA was associated with the stand-up test, whereas self-reported gait speed was associated with the two-step test and GLFS-25 in people who attended the specific health checkups in Oamishirasato City.

Author contribution

Conception and design of research: SY, SK, NY, YS, TS, SO, KT. Acquisition of data: SY, SK, NY, TS, RA, KT. Analysis and interpretation of data: SY, YS, TS, SO, KT. Writing and editing of manuscript: SY, SK, YS, TS, RA, SO, KT. Final approval of manuscript: SY, SK, NY, YS, TS, RA, TS, SO, KT

Conflict of interest

The authors declare that they have no conflicts of interest, either financial or non-financial, with the contents of this article.

References

1) Nakamura K, Ogata T.（2016）Locomotive Syndrome: Definition and Management. Clin Rev Bone Miner Metab 14, 56-67.
2) Nakamura K. Locomotive syndrome: disability-free life expectancy and locomotive organ health in a "super-aged" society.（2009）J Orthop Sci 14, 1-2.
3) Muramoto A, Imagama S, Ito Z, Hirano K, Tauchi R, Ishiguro N, Hasegawa Y.（2014）Waist circumference is associated with locomotive syndrome in elderly females. J Orthop Sci 19, 612-9.
4) Chiba D, Tsuda E, Wada K, Kumagai G, Sasaki E, Nawata A, Nakagomi S, Takahashi I, Nakaji S, Ishibashi Y.（2016）Lumbar spondylosis, lumbar spinal stenosis, knee pain, back muscle strength are associated with the locomotive syndrome: Rural population study in Japan. J Orthop Sci 21, 366-72.
5) Iizuka Y, Iizuka H, Mieda T, Tajika T, Yamamoto A, Takagishi K.（2015）Population-based study of the association of osteoporosis and chronic musculoskeletal pain and locomotive syndrome: the Katashina study. J Orthop 359 Sci 20, 1085-9.
6) Nakamura M, Kobashi Y, Hashizume H, Oka H, Kono R, Nomura S, Maeno A, Yoshida M, Ustunomiya H.（2016）Locomotive syndrome is associated with body composition and cardiometabolic disorders in elderly Japanese women. BMC Geriatr 16, 166.
7) Reiser LM, Schlenk EA.（2009）Clinical use of physical activity measures. J Am Acad Nurse Pract 21, 87-94.
8) Paterson DH, Warburton DE.（2010）Physical activity and functional limitations in older adults: a systematic

review related to Canada's Physical Activity Guidelines. Int J Behav Nutr Phys Act 7, 38.

9） Tak E, Kuiper R, Chorus A, Hopman-Rock M.（2013） Prevention of onset and progression of basic ADL disability by physical activity in community dwelling older adults: a meta-analysis. Ageing Res Rev 12, 329-38.

10） Warren JM, Ekelund U, Besson H, Mezzani A, Geladas N, Vanhees L, Experts Panel.（2010） Assessment of physical activity - a review of methodologies with reference to epidemiological research: a report of the exercise physiology section of the European Association of Cardiovascular Prevention and Rehabilitation. Eur J Cardiovasc Prev Rehabil 17, 127-39.

11） Vermeulen J, Neyens JC, van Rossum E, Spreeuwenberg MD, de Witte LP.（2011） Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review. BMC Geriatr 11, 33.

12） Pamoukdjian F, Paillaud E, Zelek L, Laurent M, Lévy V, Landre T, Sebbane G.（2015） Measurement of gait speed in older adults to identify complications associated with frailty: A systematic review. J Geriatr Oncol 6, 484-96.

13） Howe TE, Rochester L, Neil F, Skelton DA, Ballinger C.（2011） Exercise for improving balance in older people. Cochrane Database Syst Rev CD004963.

14） Lopopolo RB, Greco M, Sullivan D, Craik RL, Mangione KK.（2006） Effect of therapeutic exercise on gait speed in community-dwelling elderly people: a meta-analysis. Phys Ther 86, 520-40.

15） Mahe G, Ouedraogo N, Marchand J, Vielle B, Picquet J, Leftheriotis G, Abraham P.（2011） Self-reported estimation of usual walking speed improves the performance of questionnaires estimating walking capacity in patients with vascular-type claudication. J Vasc Surg 54, 1360-5.

16） Yoshimura N, Muraki S, Oka H, Tanaka S, Ogata T, Kawaguchi H, Akune T, Nakamura K.（2015） Association between new indices in the locomotive syndrome risk test and decline in mobility: third survey of the ROAD study. J Orthop Sci 20, 896-905.

17） Physical activity guidelines for health promotion 2013. Ministry of Health, Labour and Welfare.（2013） http://www0.nih.go.jp/.

18） Ogata T, Muranaga S, Ishibashi H, Ohe T, Izumida R, Yoshimura N, Iwaya T, Nakamura K.（2015） Development of a screening program to assess motor function in the adult population: a cross-sectional observational study. J Orthop Sci 20, 888-95.

19） Seichi A, Hoshino Y, Doi T, Akai M, Tobimatsu Y, Iwaya T.（2012） Development of a screening tool for risk of locomotive syndrome in the elderly: the 25-question Geriatric Locomotive Function Scale. J Orthop Sci 17, 163-72.

20） Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, Oja P.（2003） International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 35, 1381-95.

21） Chasan-Taber L, Erickson JB, McBride JW, Nasca PC, Chasan-Taber S, Freedson PS.（2002） Reproducibility of a self-administered lifetime physical activity questionnaire among female college alumnae. Am J Epidemiol 155, 282-9.

22） Friedenreich CM, Courneya KS, Bryant HE.（1998） The lifetime total physical activity questionnaire: development and reliability. Med Sci Sports Exerc 30, 266-74.

23） Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS.（2011） 2011 Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc 43, 1575-81.

24） Vardar-Yagli N, Sener G, Saglam M, Calik-Kutukcu E, Arikan H, Inal-Ince D, Savci S, Altundag K, Kutluk T, Ozisik Y, Kaya EB.（2015） Associations among physical activity, comorbidity, functional capacity, peripheral muscle strength and depression in breast cancer survivors. Asian Pac J Cancer Prev 16, 585-9.

25） Muranaga S.（2001） Evaluation of the muscular strength of the lower extremities using the standing movement and clinical application. J Showa Med Assoc 61, 362-7（in Japanese）.

26） Heneweer H, Vanhees L, Picavet HS.（2009） Physical activity and low back pain: a U-shaped relation? Pain 143, 21-5.

27） Hinrichs T, von Bonsdorff MB, Törmäkangas T, von Bonsdorff ME, Kulmala J, Seitsamo J, Nygård CH, Ilmarinen J, Rantanen T.（2014） Inverse effects of midlife occupational and leisure time physical activity on mobility limitation in old age--a 28-year prospective follow-up study. J Am Geriatr Soc 62, 812-20.

28） Akune T, Muraki S, Oka H, Tanaka S, Kawaguchi H, Nakamura K, Yoshimura N.（2014） Exercise habits during middle age are associated with lower prevalence of sarcopenia: the ROAD study. Osteoporos Int 25, 1081-8.

29） Vita AJ, Terry RB, Hubert HB, Fries JF.（1998） Aging, health risks, and cumulative disability. N Engl J Med 338, 1035-41.