decreases in levels of sex steroid hormones [7, 8], impaired growth hormone and insulin-like growth factor-I signaling and activity with aging [9, 10], and changes in nutritional status, including vitamin D insufficiency [11]. Previous studies have shown a positive association between lean mass and BMD in postmenopausal women [12, 13]. Sarcopenia and osteoporosis may thus act together. The prevalence of sarcopenia has been reported as 10–52 % in the postmenopausal population, depending on the reference method used and the population examined [2]. However, the prevalence of sarcopenia in osteopenic and osteoporotic women has not been fully evaluated.

Given this background, the aims of this study were to examine associations between sarcopenia and osteopenia/osteoporosis in Japanese women ≥40 years old, and to evaluate the prevalence of sarcopenia among Japanese women with osteopenia and osteoporosis.

Materials and methods

Subjects

A total of 2400 consecutive women ≥40 years old (range, 40–88 years) who visited our orthopedic outpatient clinic and underwent whole-body and regional (lumbar spine and total hip) dual-energy X-ray absorptiometry (DXA) (QDR 4500A; Hologic, Waltham, MA, USA) were enrolled in this study. All subjects were orthopedic patients who had minor symptoms (i.e., sprain, contusion, transient joint pain, etc.) and requested examination for osteoporosis, or were examinees in a regional screening program for osteoporosis who were referred to our clinic for confirmation of whether osteoporosis was present. All subjects were informed about the objectives of DXA and consented. Subjects with a past history of medication using anti-osteoporosis drugs, malignancy, corticosteroid use, bone metabolic disorders other than osteoporosis (i.e., osteomalacia, hyperparathyroidism, etc.), paralysis or inability to walk for any reason (i.e., myelopathy, paraplegia, severe osteoarthritis, etc.) were excluded.

Definitions of osteopenia and osteoporosis

Osteopenia and osteoporosis were diagnosed using the criteria of the World Health Organization (WHO) [1]. Osteopenia was defined as a BMD more than 1.0 standard deviation (SD) below the young adult mean, but less than 2.5 SDs below this value (T-score < -1 and > -2.5), and osteoporosis was defined as a BMD 2.5 SDs or more below the young adult mean (T-score ≤ -2.5). The BMDs were measured from DXA of the lumbar spine (L2–L4) and total hip.

Sarcopenia definition

From the whole-body composition data obtained using DXA, appendicular skeletal muscle mass was calculated as the sum of skeletal muscle mass in the arms and legs, assuming that all non-fat and non-bone tissue is skeletal muscle [14, 15]. The DXA measurement methods and validation have been reported elsewhere [16, 17]. Relative skeletal mass index (RSMI) was derived from the appendicular skeletal muscle mass in kilograms divided by the square of the height in meters [14, 18]. Sarcopenia was considered present for an RSMI more than 2 SDs below the mean in young women [14]. In this study, the cut-off value for sarcopenia (<5.46 kg/m^2 for women) was referenced from normative data from the Japanese population using the same DXA device (QDR 4500A; Hologic) [19].

Prevalences of sarcopenia, osteopenia, and osteoporosis

The 2400 subjects were divided into five groups according to age decade: 40–49 ($n = 105$); 50–59 ($n = 459$); 60–69 ($n = 825$); 70–79 ($n = 874$); and 80–89 ($n = 137$) years. Prevalences of sarcopenia, osteopenia, and osteoporosis in each age group were then estimated. Prevalences of sarcopenia in subjects with osteopenia or osteoporosis in the total study population and in each age group were further calculated.

Statistical analyses

The correlation between estimated variables was analyzed using Pearson's correlation coefficient and simple regression analysis. Further analyses using multiple regression were conducted to evaluate the impact of RSMI on BMD. The association between sarcopenia and osteopenia/osteoporosis was investigated using the Chi-square test for independence. Values of $p < 0.05$ were considered statistically significant.

Results

Characteristics of the 2400 participants in this study are shown in Table 1. The correlations between variables are listed in Table 2. Significant and marginal/moderate positive correlations were observed among RSMI and lumbar spine/total hip BMDs. The RSMI showed a strong positive correlation with BMI. Age showed a significant, marginal positive correlation with BMI and a significant, marginal/moderate negative correlations with lumbar spine/total hip BMDs.

Multiple regression analysis on lumbar spine BMD using age, BMI, and RSMI as independent variables

Table 1 Characteristics of study subjects ($n = 2400$)

Variables	Mean	SD	Range
Age (years)	66.3	9.2	40–88
Height (cm)	151.7	6.4	127.0–172.0
Weight (kg)	53.0	8.5	25.0–110.0
Body mass index (kg/m^2)	23.1	3.4	13.6–41.9
Relative skeletal mass index (kg/m^2)	6.15	0.72	4.15–9.53
Lumbar spine-BMD (g/cm^2)	0.810	0.174	0.311–2.077
Total hip-BMD (g/cm^2)	0.719	0.127	0.320–1.230

BMD bone mineral density, *SD* standard deviation

Table 2 Correlations between estimated variables

	Age	BMI	RSMI	LS-BMD	Total hip-BMD
Age		0.124*	0.056	−0.270*	−0.375*
BMI			0.709*	0.237*	0.336*
RSMI				0.197*	0.274*
LS-BMD					0.636*
Total hip-BMD					

Data represent Pearson's correlation coefficient, *r*

BMI body mass index, *RSMI* relative skeletal mass index, *LS* lumbar spine, *BMD* bone mineral density

* $p < 0.0001$

Table 3 Multiple regression analysis on lumbar spine-BMD in study subjects

Variables	Coefficient (r)	Significance (p)
Intercept	0.842	<0.0001
Age	−0.006	<0.0001
BMI	0.013	<0.0001
RSMI	0.010	0.1281

BMI body mass index, *RSMI* relative skeletal mass index, *BMD* bone mineral density

identified age and BMI as significant contributors for lumbar spine BMD, but RSMI did not reach the level of statistical significance (Table 3). Multiple regression analysis for total hip BMD revealed that in addition to age and BMI, RSMI was also selected as a significant contributor to total hip BMD (Table 4).

A Chi-square test for independence showed a significant association between sarcopenia defined using RSMI and osteopenia/osteoporosis defined using both lumbar spine BMD and total hip BMD ($p < 0.0001$).

When osteopenia and osteoporosis were defined using lumbar spine BMD, the prevalence of osteopenia increased after the 50s and the prevalence of osteoporosis gradually increased with age (Fig. 1). When osteopenia and osteoporosis were defined by total hip BMD, prevalence of osteopenia increased with age decade, but decreased slightly in the 80s , while the prevalence of osteoporosis increased exponentially with age group (Fig. 2). Prevalence of sarcopenia as defined using RSMI in this population was higher in the 40s compared to other age groups, and after the 50s , the prevalence appeared to almost plateau (Fig. 3).

In both definitions of osteopenia/osteoporosis by BMD measurement of the lumbar spine and total hip, the prevalence of sarcopenia defined with RSMI in subjects with osteopenia (16.8 or 17.8 %) was higher than the prevalence of sarcopenia in subjects with normal BMD (10.4 or 9.0 %), and the prevalence of sarcopenia in subjects with osteoporosis (20.4 or 29.7 %) was higher than the prevalence of sarcopenia in subjects with osteopenia. This relationship (lowest prevalence of sarcopenia in subjects with normal BMD and highest in osteoporotic subjects) was observed in all age groups (Figs. 4, 5).

Table 4 Multiple regression analysis on total hip-BMD in study subjects

Variables	Coefficient (r)	Significance (p)
Intercept	0.747	<0.0001
Age	−0.006	<0.0001
BMI	0.013	<0.0001
RSMI	0.009	0.0285

BMI body mass index, *RSMI* relative skeletal mass index, *BMD* bone mineral density

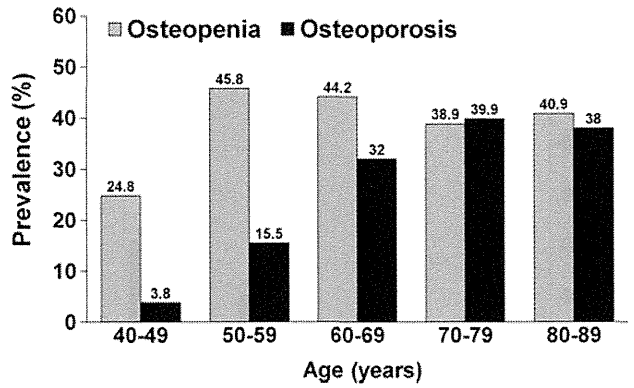


Fig. 1 Prevalences of osteopenia and osteoporosis with age, as evaluated by bone mineral density of the lumbar spine

Discussion

Sarcopenia and osteoporosis represent significant health burdens among postmenopausal women [5]. Associations with sarcopenia and osteopenia/osteoporosis in women have been reported in several studies. Gillette-Guyonnet et al. [20] reported that among 129 healthy French women, appendicular skeletal muscle mass was significantly lower in osteoporotic women than in age- and sex-matched non-osteoporotic controls. Walsh et al. [18] investigated the prevalence of sarcopenia defined using RSMI in 213 healthy pre- and postmenopausal volunteers in the United States (97 % Caucasian) and reported that the prevalence of sarcopenia in that sample was 11.7 %, with prevalences of 12.5 % in premenopausal osteopenic women, 25 % in postmenopausal women with osteopenia, and 50 % in postmenopausal women with osteoporosis. Di Monaco et al. [4] recently assessed the prevalence of sarcopenia evaluated with RSMI and associations with osteoporosis in 313 hip-fracture women, and reported that 58 % of subjects were sarcopenic, whereas 74 % were osteoporotic. They concluded that the high prevalence of sarcopenia and its significant association with osteoporosis was present in a sample of hip-fracture women [4]. The present study with a larger number of Japanese women demonstrated significant associations of lumbar spine/total hip BMD and RSMI, and the prevalence of sarcopenia was highest in osteoporotic subjects, followed by osteopenic subjects, and lowest in normal BMD subjects in all age decade groups from the 40 s to 80 s.

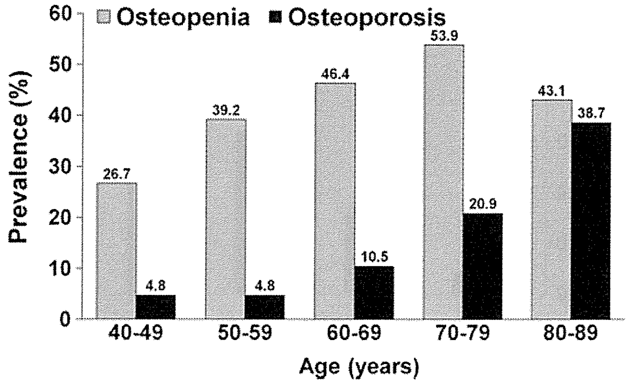


Fig. 2 Prevalences of osteopenia and osteoporosis with age, as evaluated by bone mineral density of the total hip

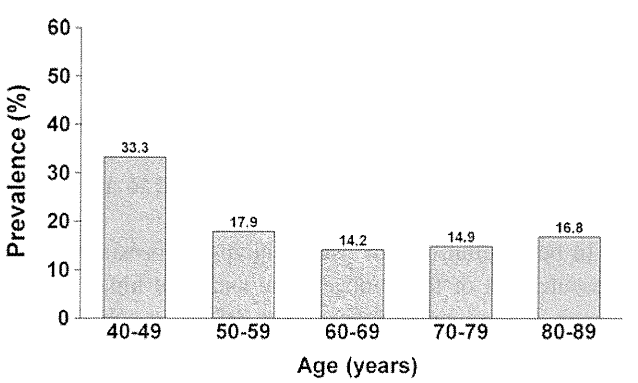
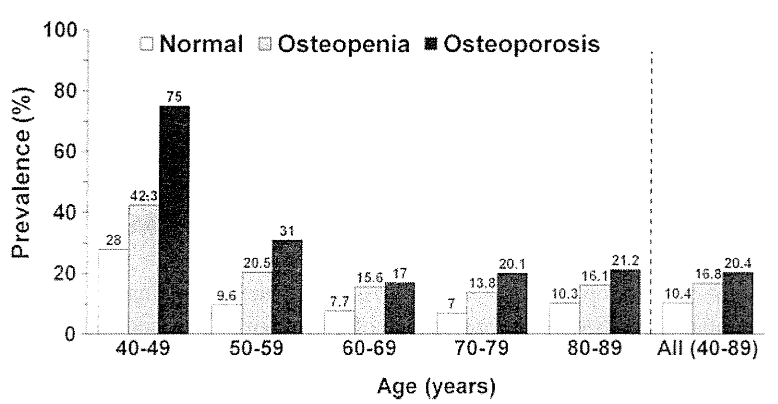


Fig. 3 Prevalence of sarcopenia with age

A study from the Third National Health and Nutrition Examination Survey (NHANES III) in the United States showed that prevalence of sarcopenia in women as estimated using bioelectrical impedance analysis (BIA) increased with age [21]. In the present study, osteopenia and osteoporosis were significantly associated with age, as with the wider literature including a report from the WHO [1]; however, RSMI and sarcopenia showed no significant association with age. Although the evaluation method in this study (RSMI) differed from that used in NHANES III (BIA), this discrepancy warrants closer attention. Study samples in the present study may have been biased compared to the normal population, because all participants in this study were subjects visiting an orthopedic clinic. Thus, the study participants might have had several underlying diseases/conditions modifying muscle mass and thus affecting the results. However, a cohort survey in Japan with a sample size of 2419 participants aged in their 40–80s showed that muscle strength (grip and knee extensor) decreased significantly with age in both men ($n = 1200$) and women ($n = 1219$), although age-related declines in the prevalence of sarcopenia as evaluated using RSMI were observed only in men, not in women [22]. Kirchengast et al. [23] also reported that significant age-related declines in lean body mass as evaluated with RSMI were observed only in men, not in women, among 282 healthy Austrian subjects aged 60–92 years. The reasons

Fig. 4 Prevalences of sarcopenia in normal, osteopenic, and osteoporotic subjects with age, as evaluated by bone mineral density of the lumbar spine



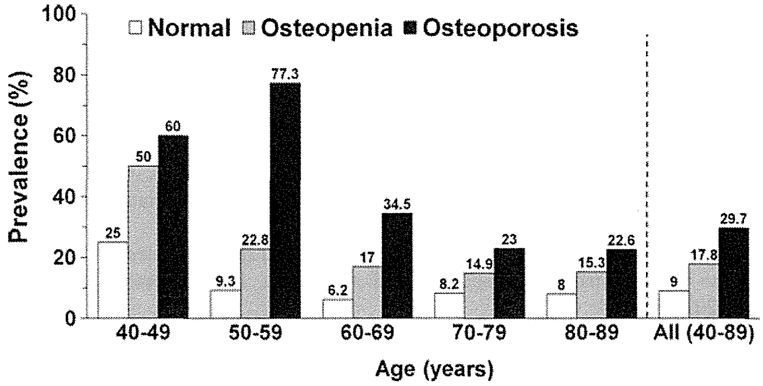


Fig. 5 Prevalences of sarcopenia in normal, osteopenic, and osteoporotic subjects with age, as evaluated by bone mineral density of the total hip

why these studies did not show age-related increases in sarcopenia among women remain unclear, but sex-specific differences may exist when sarcopenia is evaluated using RSMI.

In the present study, significant positive correlations between lumbar spine BMD and total hip BMD were observed, as previously reported [24]. However, multiple regression analysis showed that a significant impact of RSMI on BMD was only seen for total hip BMD, and not for lumbar spine BMD. We speculated that this discrepancy between total hip and lumbar spine BMDs might have been primarily attributable to the existence of spondylosis, which affects lumbar spine BMD. Although we could not evaluate the degree of spondylosis because spine X-rays were not available for many participants in this study population, previous studies have shown that lumbar osteophyte formation and intervertebral disc degeneration correlate positively with BMD [24]. In addition, from the perspective of muscle and bone interactions, RSMI of the arms and legs is considered to have a more significant relationship with BMD from an extremity (total hip BMD) rather than spine BMD.

The importance of BMD measurement for osteopenia/osteoporosis screening is widely accepted [1]. Screening for sarcopenia should also now be considered, because sarcopenia represents a major cause of disability and increased health costs, particularly among older individuals [2]. In this study, BMD and RSMI were simultaneously examined by DXA. As suggested by Walsh et al. [18], simultaneous screening for sarcopenia during BMD examinations by DXA may be of value in identifying osteopenic/osteoporotic women with sarcopenia, a group that may be most in need of exercise interventions to increase muscle and BMD.

Several limitations should be addressed. First, the definition of sarcopenia in this study only referred to RSMI, because the majority of diagnostic thresholds for sarcopenia have been developed based on this method [2, 5, 14, 18, 19, 25]. However, muscle mass does not correlate directly with muscle strength [5], and the European Working Group on Sarcopenia in Older People (EWGSOP) recommends the diagnosis of sarcopenia based on documentation of low muscle mass plus low muscle function (strength or performance) [25]. If we could have evaluated muscle function in addition to muscle mass in this study, age-related associations between sarcopenia and osteopenia/osteoporosis might have become more apparent. In future studies, for example, walking velocity should be included as a functional parameter in the definition of sarcopenia. Second, although the sample size was considered large, the present data cannot be generalized to the overall population, because the subject cohort may have suffered selection bias in that all subjects had visited orthopedic clinics. Further community-based studies with normal populations to evaluate both muscle mass and function are required to confirm the present findings.

In conclusion, this study examined associations between sarcopenia and osteopenia/osteoporosis in a total of 2400 Japanese women. The RSMI showed significant positive correlations with BMDs of the lumbar spine and total hip. Prevalence of sarcopenia defined with RSMI was highest in subjects with osteoporosis, followed by subjects with osteopenia, and lowest in subjects with normal BMD. These results suggest that sarcopenia is significantly associated with osteopenia and osteoporosis in Japanese women. However, the results should be interpreted with care, as the subject cohort may have suffered selection bias in that all subjects had visited orthopedic clinics.

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Conflict of interest None of the authors have any conflicts of interest to declare.

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Spinal sagittal contour affecting falls: Cut-off value of the lumbar spine for falls

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ABSTRACT

Spinal deformities reportedly affect postural instability or falls. To prevent falls in clinical settings, the determination of a cut-off angle of spinal sagittal contour associated with increase risk for falls would be useful for screening for high-risk fallers. The purpose of this study was to calculate the spinal sagittal contour angle associated with increased risk for falls during medical checkups in community dwelling elders. The subjects comprised 213 patients (57 men, 156 women) with a mean age of 70.1 years (range, 55–85 years). The upright and flexion/extension thoracic kyphosis and lumbar lordosis angles, and the spinal inclination were evaluated with SpinalMouse®. Postural instability was evaluated by stabilometry, using the total track length (LNG), enveloped areas (ENV), and track lengths in the lateral and anteroposterior directions (X LNG and Y LNG, respectively). The back extensor strength (BES) was measured using a strain-gauge dynamometer. The relationships among the parameters were analyzed statistically. Age, lumbar lordosis, spinal inclination, LNG, X LNG, Y LNG, and BES were significantly associated with falls ($P < 0.05$). Multivariate logistic regression analyses revealed that lumbar lordosis was the most significant factor ($P < 0.01$). Univariate logistic regression analyses for falls about lumbar lordosis angles revealed that angles of 3° and less were significant for falls. The present findings suggest that increased age, spinal inclination, LNG, X LNG, Y LNG, and decreased BES and lumbar lordosis, are associated with falls. An angle of lumbar lordosis of 3° or less was associated with falls in these community-dwelling elders.

1. Introduction

Falls that result in fractures reduce quality of life. Approximately 30% of people aged 65 years and over fall each year, and about 20% of such incidents require medical attention [1–3]. Several factors such as aging, muscle weakness, home hazards, and psychotropic medication have been reported as risk factors for falls [3]. Spinal kyphosis arises from osteoporosis, weak back muscle strength, and/or degenerative spondylosis with aging. Kyphosis, which limits the activities of daily living and impairs the quality of life, is also considered to be one of the important causes of falls [4–7]. Furthermore, postural instability, which correlates with spinal deformities, is considered to be a risk factor for falls [8–11]. Regarding the relationships between postural instability and sagittal spinal contour, a loss of lumbar lordosis affects an increasing of spinal inclination (forward stooped posture) and also correlates with postural instability and the propensity to fall [12]. Furthermore, a previous study demonstrated that a loss of lumbar lordosis, an increase in spinal inclination, and postural imbalance were significantly higher in subjects with falls than in subjects without falls or fear of falls [11]. Therefore, spinal deformities may be significant risk factors for falls. However, precise data regarding the significant factors affecting falls and the extent of spinal deformities remain unclear. Moreover, a cut-off value of sagittal spinal contour for causing falls is unknown. With the aim to identify in the clinic setting any elders who are at risk for falls, a critical cut-off angle of sagittal spinal contour associated with falls would be helpful for screening fallers. Therefore, the aims of the present study were to investigate if sagittal spinal contour factors correlated with falls, and to determine if a cut-off value of sagittal spinal contour associated with falls among community-dwelling individuals.

2. Methods

2.1. Subjects

A cross sectional study was conducted each year from 2003 to 2009. The subjects comprised 213 patients (57 men, 156 women) with a mean age of 70.1 years (range 55–85 years) who participated in medical checkups for community dwellers in Akita, Japan. All the participants were able to walk alone and did not display any apparent neurological or metabolic disorders. The history of falls within the past year was recorded by a self report questionnaire.

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Table 1
Characteristics of the 213 subjects and variables affecting falls evaluated between fallers and non-fallers.

Variables	Total (n = 213)	Fallers (n = 29)	Non-fallers (n = 184)	$P^{\dagger}$
Number/percentage of women	156/73.2	24/82.8	132/71.7	
Age (years)	70.1 (7.9)	73.6 (7.7)	70.1 (9.8)	0.020*
Body weight (kg)	54.2 (8.3)	51.7 (8.7)	55.1 (9.6)	0.123
Height (cm)	153.2 (8.4)	150.6 (8.1)	153.9 (8.7)	0.197
Thoracic kyphosis (°)	34.0 (14.5)	33.3 (14.7)	34.4 (14.4)	0.396
Lumbar lordosis (°)	11.1 (15.5)	3.8 (20.5)	11.9 (14.3)	0.035*
Spinal inclination (°)	6.0 (8.4)	10.9 (12.2)	5.8 (7.9)	0.017*
Thoracic mobility (°)	22.2 (22.2)	19.2 (24.1)	22.6 (21.6)	0.421
Lumbar mobility (°)	36.9 (22.3)	35.9 (25.5)	36.4 (21.7)	0.810
Mobility of spinal inclination (°)	102.4 (33.7)	95.0 (43.2)	101.9 (32.9)	0.491
Stabilometry				
LNG (mm)	306.7 (174.8)	432.1 (282.0)	294.1 (146.0)	0.029*
ENV (mm^2)	126.9 (112.6)	188.0 (155.7)	122.0 (102.0)	0.051
X LNG (mm)	154.2 (80.1)	198.8 (116.2)	150.1 (70.5)	0.017*
Y LNG (mm)	225.7 (151.7)	336.9 (243.9)	214.5 (127.0)	0.046*
BES (kg)	14.4 (8.3)	9.0 (8.6)	14.9 (8.3)	0.001*

Notes: Values represent the mean (±SD); LNG, total track length; ENV, enveloped area; X LNG, lateral sway length; Y LNG, anteroposterior sway length; BES, back extensor strength.
* Significant difference.
† Mann–Whitney *U* test.

2.2. Measurements of spinal sagittal contour and mobility

The parameters of sagittal spinal contour were evaluated using SpinalMouse® (Idiag, Volkerswill, Switzerland), which is a computer-assisted and non-invasive device for measuring spinal shape and mobility using surface-based techniques, and therefore reflects the shape of the dorsal trunk in appearance [13]. Measurements were accomplished by sliding this device along the spinal processes from the cephalad end of the thoracic spine to the sacrum at posterior superior iliac spine level while the subject stood with legs together. The angles of thoracic kyphosis (angle between T1 and T12), lumbar lordosis (angle between T12 and S1), and spinal inclination (angle between a straight line from T1 to S1 and the true vertical line) were evaluated. The spinal inclination reflected a forward stooped posture. All the parameters were measured in neutral standing, trunk flexion, and trunk extension positions without any support to investigate the influence of spinal mobility on the postural instability. Repetition of the measurement with the subject in trunk flexion and extension of the spine allowed measurements of spinal mobility. The mobility range of spinal inclination, which reflects the anteroposterior range of motion by the trunk, comprising the thoracic, lumbar, and sacral mobility, was also measured at maximum trunk flexion/extension. All the spinal data were measured and then calculated automatically, requiring only a short amount of time to complete the measurements. The intra-class correlation coefficients for the measurements with SpinalMouse® were 0.92–0.95 [14].

2.3. Measurement of postural instability

Stabilometry was performed using a JK-101® force platform (Unimec, Tokyo, Japan) with construction based on the strain-gauge principle. Each patient stood on the platform in a naturally upright posture with their upper limbs aligned with the sides of the body, their legs together, and their eyes open. Measurements were performed by sampling signals of the center of pressure (COP) for 20 s at a frequency of 20 Hz using a microcomputer. The following parameters indicating postural sway (imbalance) were extracted from the COP time series: total track length (LNG) indicating the sway length, enveloped area (ENV) indicating the spatial spread of the swaying, track length in the lateral direction (X LNG) indicating the lateral sway length, and track length in the anteroposterior direction (Y LNG) indicating the anteroposterior sway length. These parameters were also described and used in previous studies [12,15]. The intra-class correlation coefficients for the postural sway measurements with the stabilometer were 0.71–0.95 [16,17].

2.4. Measurement of back extensor strength

Isometric back extensor strength (BES) in the prone position was measured using a DPU-1000N Digital Force Gauge® strain-gauge dynamometer (Imada, Toyohashi, Japan). The measurements were performed twice, and the mean force was calculated. Regarding the precision of the measurements, the coefficient of variation was 2.3% [14].

2.5. Statistical analysis

All the data were analyzed using StatView® statistical software (SAS Institute, Cary, NC). To evaluate factors associated with falls, the relationships among age, body weight, height, sagittal spinal contour, spinal mobility, postural instability, and BES were analyzed using the Mann–Whitney *U* test. Since spinal posture, postural instability, and falls differ by age and sex, multivariate logistic regression analyses after adjusting for age and sex were performed for the significant variables to reveal the most significant parameters of sagittal spinal contour. Thereafter, the subjects were divided into two subgroups based on each one degree of significant sagittal spinal angle to evaluate the cut-off values. The relationships between these subgroups and falls were analyzed using univariate logistic regression analyses after adjustment for age and sex. Taking lumbar lordosis at 5° as an example of the subgroups, the subjects were divided into a 6° or more group and a 5° or less group, and analyzed as described above. The same method was applied for angles from −2° to 11°. The correlations between the variables were estimated to be absent ($r \leq 0.2$), weak ($0.2 < r \leq 0.4$), moderate ($0.4 < r \leq 0.7$), or strong ($r > 0.7$) according to the correlation coefficients. Values of $P < 0.05$ were considered statistically significant.

3. Results

The mean values for the age, body weight, height, angles of thoracic kyphosis, lumbar lordosis, and spinal inclination, thoracic and lumbar mobility, mobility of spinal inclination, parameters of postural instability, and BES are shown in Table 1. The fallers group comprised 29 subjects and the non-fallers group comprised 184 subjects.

The fallers were lighter and shorter than the non-fallers but this was not significant. The number and percentage of women were higher in the fallers group. Mann–Whitney *U* tests revealed that age, angle of lumbar lordosis, spinal inclination, LNG, X LNG, Y LNG, and BES were significantly associated with the history of falls ($P < 0.05$).

Multivariate logistic regression analyses for falls after adjustment for age and sex among the significant parameters, including angles of lumbar lordosis and spinal inclination, LNG, X LNG, Y LNG, and BES, revealed that the angle of lumbar lordosis was the only and most significant factor (Table 2). Therefore, lumbar lordosis was selected as the most significant factor among the spinal parameters. Univariate logistic regression analyses after adjustment for age and sex to evaluate the cut-off value for falls revealed

Table 2
Multivariate logistic regression analyses after adjustment for age and sex.

	Coefficient	SE	χ^2-value	*P*-value
Lumbar lordosis angle (°)	−0.049	0.022	5.167	0.023*
Spinal inclination (°)	−0.018	0.036	0.253	0.615
LNG (mm)	0.009	0.013	0.457	0.499
X LNG (mm)	−0.007	0.009	0.669	0.413
Y LNG (mm)	−0.005	0.012	0.149	0.699
BES (kg)	−0.032	0.053	0.361	0.548

Notes: SE, standard error; LNG, total track length; X LNG, lateral sway length; Y LNG, anteroposterior sway length; BES, back extensor strength.
* Statistical significance.

Table 3
P-values for comparisons between subgroups divided by each lumbar lordosis angle and falls.

Lumbar lordosis (°)	P-value[†]
8	0.079
7	0.072
6	0.174
5	0.098
4	0.062
3	0.047*
2	0.023*
1	0.023*
0	0.007*
−1	0.015*

* Statistical significance.
† Univariate logistic regression analyses after adjustment for age and sex.

that angles of lumbar lordosis at 3° and less showed a significant correlation with falls ($P < 0.05$) (Table 3). Thirteen out of fifty four patients (23%) with a lumbar lordosis of 3° and less actually fell in the previous year.

The correlations among age, spinal alignment (thoracic kyphosis, lumbar lordosis, and spinal inclination), LNG, and BES are shown in Table 4. Regarding the sagittal spinal contour parameters, lumbar lordosis showed significant correlations with all the other spinal alignment factors, whereas thoracic kyphosis only showed a weak correlation with lumbar lordosis. Spinal inclination displayed a significant moderate correlation with lumbar lordosis, but not with thoracic kyphosis.

The loss of lumbar lordosis and the angle of spinal inclination showed significant correlations with age, LNG, and BES. In contrast, the angle of thoracic kyphosis showed no significant correlations with age and BES, and an absent correlation with LNG. Age showed a significant positive but weak correlation with LNG and a significant negative moderate correlation with BES. LNG also showed a significant negative moderate correlation with BES.

4. Discussion

Among the previously reported causal factors for falls or fall-related fractures [3], postural instability, which is influenced by loss of lumbar lordosis [12], is considered to be an important risk factor for falls [8–11]. In the present study, sagittal spinal contour factors were evaluated with a computer-assisted device (Spinal-Mouse®), postural instability was assessed using stabilometry, and BES was measured using a strain-gauge dynamometer. These devices are convenient for studies of community-dwelling elders because of their non-invasiveness, ease of handling, and the limited time needed for the measurements. The reliability of this device has already been well described [13–17].

Loss of spinal lordosis, decreasing range of spinal motion, and back muscle weakness have been reported as critical factors for predicting falls [11]. To prevent falls and fractures associated with spinal deformities, and to screen patients with spinal deformities who might require further medical care, determination of a cut-off angle of spinal contour associated with falls would improve clinical management. Lumbar lordosis was found to be the most significant factor associated with falls in the present study, and the critical cut-off value of lumbar lordosis associated with falls was 3° or less. This angle can be used during medical checkups to screen subjects who are suspected to be at risk for falling.

X-rays, the gold standard for evaluation of sagittal spinal alignment, involves radiation exposure, and incurs higher medical costs. Screening subjects at high-risk for falls is a very important issue from the viewpoint of preventive medicine, prevention of fractures, and reduction of medical costs. Therefore, Spinal-Mouse®, which uses surface-based techniques to record spinal contours, requires little time to calculate spinal angle and requires no radiation exposure or cost to the patient, is useful and suitable for medical checkups and outpatient clinics.

Younger subjects are at less risk of falls than older subjects, and usually do not show any apparent degenerative spinal deformities. Therefore, only subjects aged 55–85 years, who had a tendency to fall and who were thought to be potential candidates for further medical care, were included in this study. Consistent with a previous report [12], we found that loss of lumbar lordosis had a significant correlation with age, while thoracic kyphosis did not. Lumbar lordosis, but not thoracic kyphosis, also showed a significant correlation with spinal inclination, and leads to an increased forward bending posture that may be related to falls. As reported previously [11], postural imbalance indicated by LNG, X LNG, and Y LNG showed a significant correlation with falls. BES also showed a significant association with falls. Moreover, BES showed a significant negative correlation with LNG, suggesting that weakness of BES would increase postural sway and imbalance, and contribute to the risk of falls.

Thoracic or thoracolumbar kyphosis is commonly accepted as the first deformity in elderly people [18]. Progression of the thoracic kyphosis by the flexor moment with anterior movement of the center of gravity aggravates the deformity. In elderly people, lumbar mobility was more severely limited because of spondylosis [19,20] and weakness of BES with aging [21] (Table 4). Consequently, compensation for thoracic kyphosis by the lumbar spine may be inhibited, thereby progressing the loss of lumbar lordosis, and the additional deformity may induce lumbar kyphosis [22]. On the other hand, severe thoracic kyphosis may be inhibited by the ribcage anatomically, such that the spinal inclination may increase significantly and be correlated with loss of lumbar lordosis, but not thoracic kyphosis, with aging as shown in Table 4. Loss of lumbar lordosis increases a forward bending posture (spinal inclination), which may induce anterior deviation of the center of gravity, postural instability, and falls.

The normal sagittal spinal contour shows thoracic kyphosis and lumbar lordosis, and the thoracic back muscles are thinner than the lumbar back muscles anatomically. Therefore, the BES measured in the present study is supposed to be mainly derived from the

Table 4
Correlations among age, spinal sagittal contour, LNG, and BES.

	Thoracic kyphosis (°)	Lumbar lordosis (°)	Spinal inclination (°)	LNG (mm)	BES (kg)
Age	0.031	−0.359**	0.457**	0.388**	−0.514**
Thoracic kyphosis (°)		0.286**	0.004	−0.177*	0.107
Lumbar lordosis (°)	0.286**		−0.542**	−0.396**	0.424**
Spinal inclination (°)	0.004	−0.542**		0.505**	−0.547**
LNG (mm)	−0.177*	−0.396**	0.505**		−0.394**
BES (kg)	0.107	0.424**	−0.547**	−0.394**	

Notes: BES, back extensor strength; LNG, total track length. Data represent Pearson's correlation coefficients (r).
* $P<0.05$.
** $P<0.001$.

lumbar extensor muscles, and this may also explain the significant correlation observed between the BES and lumbar lordosis.

The cut-off value for falls in the present study was 3° of lumbar lordosis. However, the loss of lumbar lordosis increased with aging. Some previous reports have also described that sway increases with age and is higher in women at all ages [23,24]. Further investigations will clarify the differences with other generations and/or sex.

The results of the present study show that age, lumbar lordosis, spinal inclination, LNG, X LNG, Y LNG, and BES may represent risk factors for falls. Moreover, loss of lumbar lordosis was the most significant spinal parameter correlating with falls. Precise analyses revealed that patients with an increased incidence of falls tend to have lumbar lordosis of 3° or less in this community-dwelling study. Patients with loss of lumbar lordosis should be advised of their increase risk of falling and should be considered for enrollment in a fall prevention program.

Acknowledgment

None.

Conflict of interest statement

None.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.gaitpost.2012.11.024.

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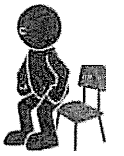

第7回 ロコモティブシンドローム対策
――ロコモコールの有効性*

安村誠司　橋本万里**

[整形外科 64 巻 13 号：1412～1415, 2013]

はじめに

介護保険法における要支援・要介護認定者数は年々増加傾向にある．また，要支援・要介護状態になるおそれのある二次予防事業対象者は，高齢者人口の 9.4％を占めている[1]．しかし，二次予防事業対象者の事業への参加率は約 1 割[1]と，参加率の低さが課題となっている．要介護リスクとして対象者がもっとも多い「運動器の機能向上」プログラムのほとんどは通所型であるが，通所しない，通所できない高齢者のほうが介護予防の必要性が高いと考えられる[2]．

要介護状態の要因の一つとして近年注目されているロコモティブシンドローム（ロコモ）は，日本整形外科学会が新たに提唱した概念[2]であり，ロコモ予防のため，主に開眼片脚立ちとスクワットの 2 種類の運動で構成されるロコモーショントレーニング（ロコトレ）が推奨されている[2～4]．通所型介護予防事業に参加しない「運動器の機能向上」の二次予防対象者に対して，筆者らは訪問型介護予防事業としての在宅における「ロコトレ」プログラムを開発した[5,6]．本プログラムでは，電話をかけてロコトレの継続を支援する「ロコモコール」を取り入れた．本稿ではロコモコールの有効性について概説する．

1．通所型介護予防プログラム不参加者を対象としたロコモコールの有効性を評価した調査

1．調査対象者

山形県天童市における 2012 年 6 月 30 日時点の二次予防事業対象者数 1,246 名であり，このうち，「運動器の機能向上」単独，もしくは他項目一つの二次予防事業対象者となった 257 名をロコトレへの声かけ対象者とした．対象者 257 名に，地域包括支援センター（包括）から参加依頼および参加意向確認の電話をした．参加意向があった 31 名に包括職員が初回調査訪問をし，本研究について改めて説明して参加同意が得られた 25 名をロコトレ参加者とした．

1）初回調査

包括職員が参加者の自宅を訪問し，聞き取り調査，開眼片脚立ち時間および椅子立ち上がり時間（5 回）の測定を実施した．「ロコトレ手帳」[7]を配布し，ロコトレの実施方法を説明した．

2）ロコトレの実施（図 1～3）

参加者は，開眼片脚立ちを左右 1 分ずつで 1 セット，スクワットを 5～6 回で 1 セットとし，1 日各 3 セットを実施することとし，実施回数を「ロコトレ手帳」に記載した．実施期間は 3ヵ月間とし，期間中，包括職員から定期的に実施状況確認の電話をした．このロコモコールと称した電話は原則週 1～3 回とした．

3）最終調査

初回調査から 3ヵ月後に包括職員が自宅を訪問し，初回調査と同様の調査・測定を実施した．

2．結　果

1）ロコトレへの参加者は 25 名で，通所型介護予防事業への参加意向を示したのは 6 名であり，二次予防事業参加者は計 31 名となり，参加率が 9.8％増加した．また，3ヵ月間ロコトレを継続した者は 23 名で，継続率は 92.0％であった．

Key words：locomotive syndrome, locomo call, validity

* Validity of locomo call

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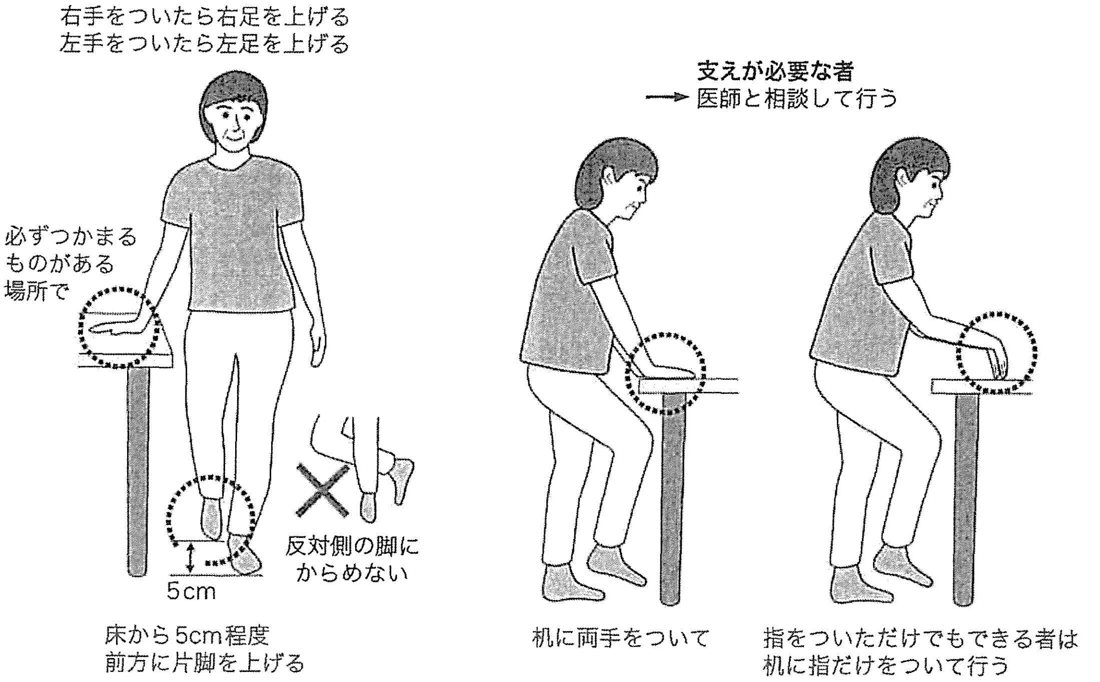

図 1．ロコトレ（1）．開眼片脚立ち．左右 1 分ずつ 1 日 3 セット行う（文献 7 より引用改変）．

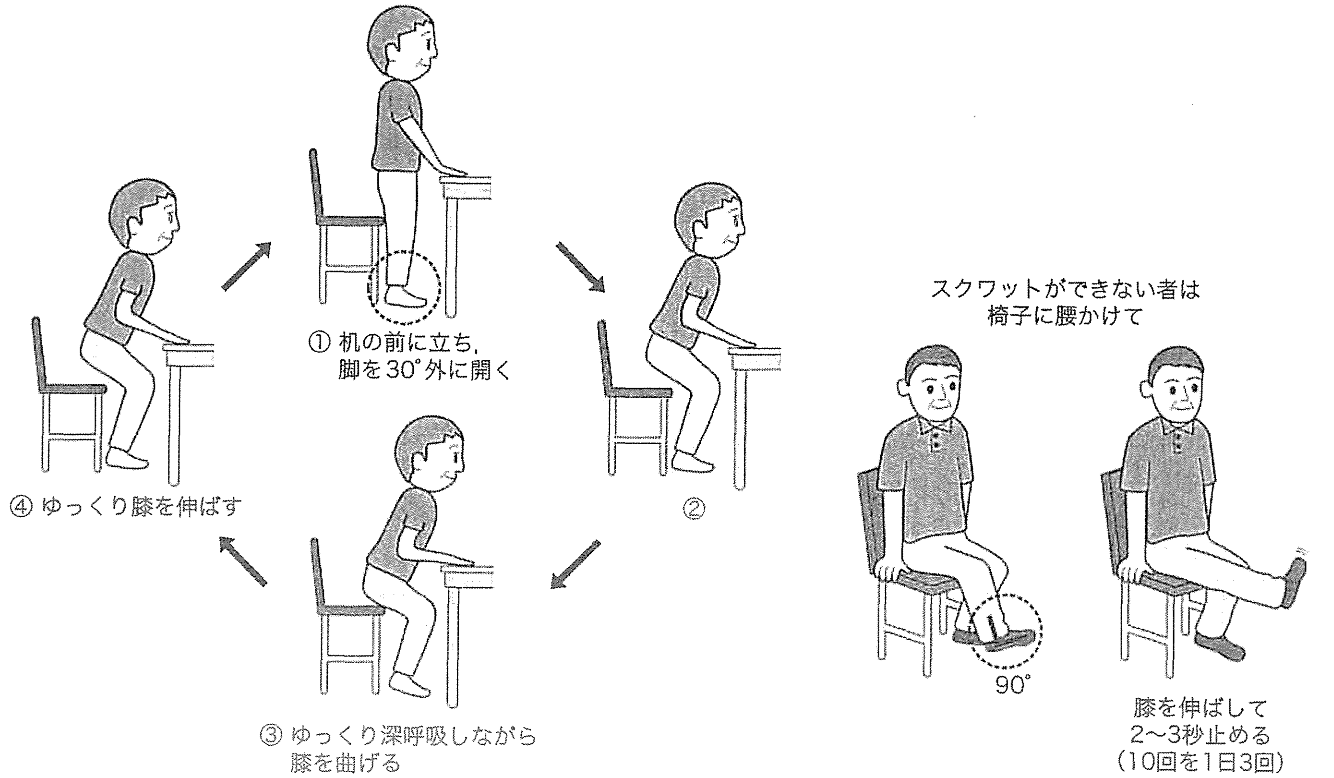

図 2．ロコトレ（2）．スクワット．深呼吸しながら 5〜6 回を 1 日 3 セット行う（文献 7 より引用改変）．

2）継続者における 3ヵ月間のロコモコール回数は，平均値 11.8 回（平均週 1 回）であった．

3）開眼片脚立ち時間は，初回調査時（19.9±25.6 秒）と比べ最終調査時（24.0±33.2 秒）に有意に延長していた（$p=0.02$）［表 1］．また椅子立ち上がり時間（5 回）では継続者全体で，初回調査時（14.7±8.2 秒）

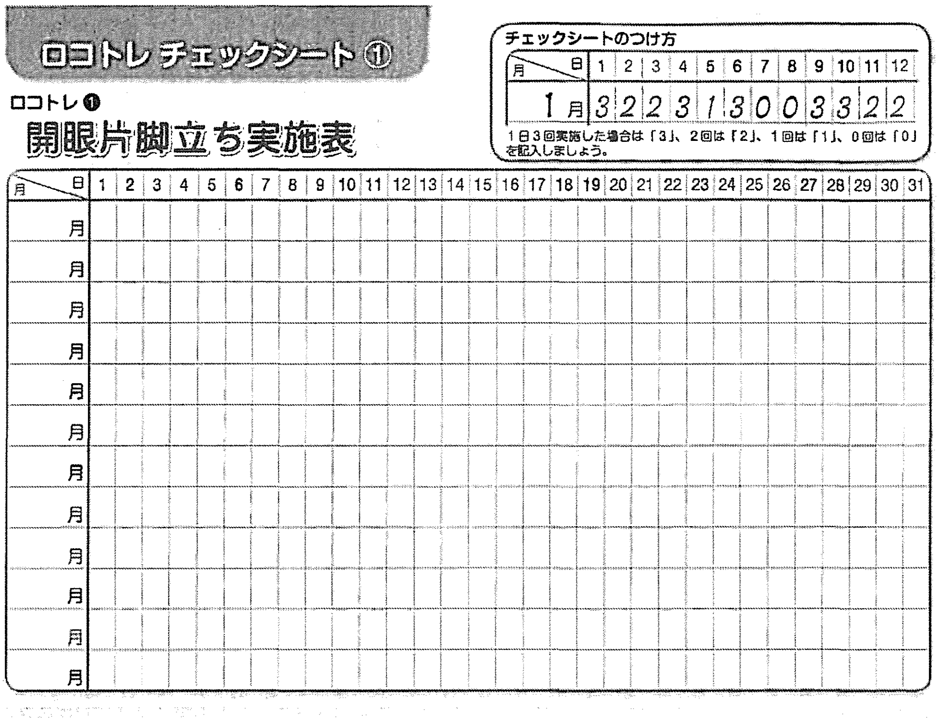

図 3. ロコトレチェックシート①（文献7より引用）

表 1. 性・年齢階級別の開眼片足立ち時間の変化

	開眼片足立ち時間［平均値（秒）±SD］		p 値
	初回調査時	最終調査時	
全　体（n=23）	19.9±25.6	24.0±33.2	0.02
性別　男（n=7）	20.2±21.2	32.8±41.8	0.02
女（n=16）	19.8±27.9	20.2±29.5	0.18
年齢　<75歳（n=5）	55.5±34.9	61.2±54.6	0.35
75歳≦（n=18）	10.1±9.2	13.7±14.4	0.01

p 値：Wilcoxon の符号付き順位和検定を行った

と比べ最終調査時（12.5±7.7秒）に有意に短縮していた（$p<0.01$）.

2．ロコモコールの有効性

ロコモコールを用いたロコトレ調査においても，高い継続率が得られた．このような高い継続率の理由として第一に，ロコトレは運動が比較的むずかしくない2種類のみであり，覚えやすく取り組みやすかったと考える．第二に，簡便であることに加え，体操の目的が「バランス力と下肢筋力を高める」と明確であることも動機づけになっていると思われる．第三に，ロコモコールによる継続的なサポートがあったことが考えられる．これは中村耕三氏（当時東京大学教授）による画期的な発案であると考える．ロコモコールの有効性についてはすでに報告されており，至適回数を検討する必要性が指摘されている[8]．本研究ではロコモコールを週1〜3回とし，参加者の希望による回数調整を認めた．ロコモコール回数は約週1回に相当する．これは昨年度の平均回数（約2回）[8]より少なかったが，継続率の低下はみられなかった．

また，「開眼片脚立ち時間」と「椅子立ち上がり時間」はいずれも改善傾向が認められ，今回実施したロコモコールを用いたロコトレは，ロコモコール回数は少ないが，身体機能に一定の効果があることが示唆された．ロコモコールの回数を減らしても効果があることから，対象者に合ったプログラムを提供できる可能性が示された．

ロコモコールが有効であった理由および意義は以下のようにまとめられる[9]．

1）「電話があったから継続できた」といった話が多数聞かれた．調査員は担当制をとり，初回調査から最終調査まで同一の調査員がかかわった．これは，同一の調査員が電話することが信頼関係を構築するうえで有用であると考えたためである．

2）ロコトレの運動自体はそれほどむずかしいものではないが，具体的なやり方や記載方法がわからなくなった場合に質問することができ，継続実施につながったこ

とも大きい．

3）本来ロコトレに関する電話であったが，症状や体調などについて聞かれることもあり，早期対応に結びついたこともある．

4）調査の期間中に検討会を開催し，調査員が気になったことや疑問に感じたことなどを出し合い，解決策をともに考え，情報の共有，対応の質の確保を図ったことも有益であった．

5）毎週電話をすることによって，結果的に高齢者の「見守り」になった．

おわりに

1）ロコモコールを取り入れたロコトレは，継続しやすいプログラムである．

2）ロコモコールを取り入れたロコトレを含む訪問型介護予防事業を実施することで，二次予防事業対象者の参加者の増加が見込まれる．

3）ロコモコールを取り入れたロコトレは，身体機能の向上に一定の効果があることが示唆された．

4）ロコモコール終了後の継続性については評価する必要があり，今後も継続した調査が必要である．

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