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# Ⅲ．研究成果の刊行物・別刷

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ORIGINAL ARTICLE

# Reference values for hand grip strength, muscle mass, walking time, and one-leg standing time as indices for locomotive syndrome and associated disability: the second survey of the ROAD study

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**Abstract**

*Background* We established reference values for hand grip strength, muscle mass, walking time, and one-leg standing time as indices reflecting components of locomotive syndrome and associated disability using a large-scale population-based sample from the second survey of the Research on Osteoarthritis/Osteoporosis Against Disability (ROAD) cohort.

*Methods* We measured the above-mentioned indices in 2,468 individuals ≥40 years old (826 men, 1,642 women; mean age 71.8 years) during the second visit of the ROAD study. Disability was defined as certified disability according to the long-term care insurance system through public health centres of each municipality.

*Results* Mean values for hand grip strength (weaker side), muscle mass of the thighs, walking time for 6 m at the usual pace, and the fastest pace for men were 32.7 kg, 7.0 kg, 5.6 s, and 3.7 s, respectively, and those for women were 20.8 kg, 5.2 kg, 5.9 s, and 4.1 s, respectively. The median values for one-leg standing time (weaker side) were 14 s for men and 12 s for women. The prevalence of disability in men aged 65–69, 70–74, 75–79, and ≥80 was 0.0, 1.0, 6.3, and 8.8%, respectively, and in women was 3.4, 3.5, 9.2, and 14.7%, respectively. There were significant associations between the presence of disability and walking time for 6 m at the usual pace and at the fastest pace, and between the presence of disability and walking speed.

*Conclusions* We established reference values for indices reflecting components of locomotive syndrome, and identified significant associations between walking ability and disability.

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## Introduction

Musculoskeletal diseases, including osteoarthritis (OA) and osteoporosis (OP), are major public health problems among the elderly that affect activities of daily living (ADL) and quality of life (QOL), leading to increased morbidity and mortality. According to the recent National Livelihood Survey by the Ministry of Health, Labour, and Welfare in Japan, OA is ranked fourth, while falls and osteoporotic fractures are ranked fifth among diseases that cause disabilities and subsequently require support for ADL [1]. Previous studies have reported increased mortality following osteoporotic fractures at the hip and other sites [2], and have estimated that a total of 47,000,000 people (21,000,000 men and 26,000,000 women) aged ≥40 years will eventually be affected by either OA or OP. Considering that the population of Japan is aging very rapidly—more than 22% of the population is aged ≥65 years [3]—a comprehensive and evidence-based prevention strategy for musculoskeletal diseases is urgently needed.

The Japanese Orthopaedic Association has proposed the term 'locomotive syndrome' to designate a condition in high-risk groups with musculoskeletal diseases who are highly likely to require nursing care [4]. Locomotive syndrome is caused by weakening of musculoskeletal organs such as bone, joint, and muscle, which in turn interferes with physical performance, especially self-transportation. Loss of locomotor abilities such as walking causes disabilities requiring support. Therefore, to prevent decline into disability, it is important to maintain a healthy range of bone, joint, muscle, and physical performance.

These four components, bone, joint, muscle, and physical performance, each have objective measurements that can be used as indices to evaluate their present condition. For example, bone mineral density (BMD) is a representative index of the condition of the bone. Joint space width (JSW), joint space area (JSA), and osteophyte area (OPA) are indices reflecting the condition of the joint. Regarding muscle, although the best index remains controversial, hand grip strength can be used to reflect muscle strength [5], and muscle mass is one index of muscle volume [6]. In addition, as objective indices of physical performance, walking speed and/or one-leg standing times are candidates [7, 8]. However, at present, it is difficult to use such indices for evaluating, diagnosing, or predicting the future occurrence and progression of locomotive syndrome in Japan, because there is little information on reference values for such indices to distinguish patients at risk from normal individuals in a large population-based cohort.

In 2005–2007, we began a large-scale population-based cohort study entitled Research on Osteoarthritis/Osteoporosis Against Disability (ROAD), consisting of 3,040 participants in three communities located in urban, mountainous, and coastal areas (baseline study). Following the baseline study, a second survey was performed in the same communities in 2008–2010, in which 2,674 inhabitants participated (second visit).

Through analysis of the baseline data of the ROAD, the age-gender distribution of BMD has been reported as an index for bone mass [3], and the medial and lateral JSW, medial and lateral JSA, OPA, and femorotibial angle of the knee have been reported as indices of the health of joints [9] in these populations. However, there is still scant information regarding the condition of the muscles and physical performance. Therefore, in the present study, we aimed to establish reference values for hand grip strength as an index of muscle power, muscle mass as an index of muscle volume, and walking time and one-leg standing time as indices of physical performance, classified by age and gender, using the data from the second visit of the ROAD study. This information is expected to be valuable for early diagnosis and prevention of locomotive syndrome. In addition, we evaluated the prevalence of disabilities in participants in the ROAD study second visit, and identified associations between hand grip strength, muscle mass, walking time, and one-leg standing time and the presence of disability.

## Participants and methods

### Participants

Reference values were obtained from the results of cross-sectional measurements of participants enrolled in the second visit of the ROAD study. The ROAD study, which began in 2005, is a nationwide prospective study comprising population-based cohorts established in three communities, such as urban, mountainous, and coastal regions in Japan. Recruitment methods for this study have been described in detail elsewhere [3]. To date, participants in the urban region, aged ≥60 years, were recruited from among those enrolled in a randomly selected cohort study from the previously established Itabashi Ward resident's registration database. The response rate was 75.6%. Participants in the mountainous and coastal regions, aged ≥40 years, were recruited from listings of resident registration. Residents aged ≤60 years in the urban area and ≤40 years in the mountainous and coastal areas who were interested in participating in the study were invited. We have completed development of a baseline database including clinical and genetic information for 3,040 inhabitants aged 23–95 years (1,061 men, 1,979 women).

The second visit of the ROAD study began in 2008 and was completed in 2010. All the participants in the baseline study were invited to participate in the second visit. In addition to the former participants, inhabitants aged ≥60 years in the urban area and those aged ≥40 years in the mountainous and coastal areas who were willing to participate in the ROAD survey performed in 2008–2010 were also included in the second visit. In addition, residents aged ≤60 years in the urban area and ≤40 years in the mountainous and coastal areas who were interested in participating in the study were invited to be examined as well as the baseline.

The inclusion criteria of participants were as follows: (1) ability to walk to the clinic where the survey was performed, (2) ability to provide self-reported data, and (3) ability to understand and sign an informed consent form. No other exclusion criteria were used.

Thus, a total of 2,674 residents (892 men, 1,782 women) aged 21–97 years participated in the second visit. In the present study, we analysed the data for 2,468 individuals (826 men, 1,642 women; mean age 71.8 years); this population comprised 956 individuals (318 men, 638 women) in the urban region, 726 individuals (258 men, 468 women) in the mountainous region, and 786 individuals (250 men, 536 women) in the coastal region who participated in the second visit and were ≥40 years old.

All the participants provided written informed consent, and the study was conducted with the approval of the ethics committees of the participating institutions.

### Hand grip strength, muscle mass, walking time, and one-leg standing time

Hand grip strength was measured bilaterally using a Toei Light handgrip dynamometer (Toei Light Co., Ltd., Saitama, Japan). Both hands were tested, and the better value was used to characterise the maximum muscle strength of the subject.

Among the 2,468 participants who participated in the second visit of the ROAD study, 778 residents (248 men, 530 women) in the coastal town of Taiji were examined to determine their segmental muscle mass using the bioelectrical impedance method (BIP; Physion MD; Physion Inc., Kyoto, Japan). We obtained values for the muscle masses of the right and left forearms, upper arms, upper limbs, quadriceps, thighs, lower legs, and lower limbs. This method had previously been validated as having a close correlation to muscle volume as measured by magnetic resonance imaging [10].

Among the 2,468 participants who participated in the second visit of the ROAD study, 1,637 residents (559 men, 1,078 women) of the mountainous town of Hidakagawa and the coastal town of Taiji were examined to determine their walking time. Walking time was measured as the time required to complete a 6-m course. All participants walked the 6-m course twice; they first walked at their usual walking speed and then repeated the course at their fastest pace.

Among the 2,468 participants who participated in the second visit of the ROAD study, one-leg standing time with eyes open was measured on both sides for 2,433 individuals (816 men, 1,617 women). The time until the raised leg was set down on the floor was measured, with a maximum time of 60 s recorded for those who could stand on one leg for at least that length of time. The shorter value of the two measurements was used as the worse side and the longer measurement as the better side for the one-leg standing time of the subject.

Mean values and standard deviations (SDs) of hand grip strength, muscle mass, and walking time were classified by gender and age group (40, 50, 60, 70, and ≥80 s) to establish age-gender reference values for the general population. However, reference values classified by gender and age group for one-leg standing time were established using median (50th percentile) values and 25th–75th percentile ranges. These values were recorded using a maximum time of 60 s for anyone who could exceed that time; thus, the data do not fit a normal distribution, and use of means and SDs is unsuitable for one-leg standing time reference values.

### *Presence of disability*

Disability in the present study was defined as 'cases requiring long-term care' as determined by the long-term care insurance system based on the Long-Term Care Insurance Act of 1997 in Japan. The procedure for identifying cases requiring long-term care is as follows: (1) each municipality establishes a long-term care approval board consisting of clinical experts, physicians, and specialists at the Division of Health and Welfare in each municipal office; (2) the long-term care approval board investigates the insured person using an interviewer-administered questionnaire consisting of 82 items regarding mental and physical condition and makes a screening judgement based on the opinion of a regular doctor; and (3) 'cases requiring long-term care' are determined according to standards for long-term care certification uniformly and objectively applied nationwide [11].

During the 3 years between the baseline and the second visit of the ROAD study, we annually obtained information on the participating residents regarding deaths, changes of residence, and presence or absence of certified disability according to the long-term care insurance system from the public health centres of the participating municipalities.

*Statistical analysis*

All statistical analyses were performed using Stata statistical software (Stata, College Station, TX, USA). Differences in the values of the indices were tested for significance using analysis of variance for comparisons among multiple groups. Scheffé's least significant difference test was then used for pairs of age groups.

To ascertain associations between the presence of disability and hand grip strength, muscle mass, walking time, and one-leg standing time, logistic regression analyses were performed using the presence of disability (yes, 1; no, 0) as an objective factor, and values for hand grip strength, muscle mass, walking time, and one-leg standing time as the explanatory factor after adjusting for age, gender, and body mass index (BMI, $kg/m^2$).

## Results

Characteristics of participants

Summary characteristics including age, height, weight, and BMI of the participants in the present study are shown in Table 1. Two-thirds of the 2,468 subjects were women, and the mean age of the female participants was 1 year younger than that of the male participants. Height and weight were significantly lower for women than for men, but no significant difference in BMI was noted between the genders. All anthropometric measurements other than BMI of females tended to decrease with age. BMI of women in their 80s and older was significantly lower than that in younger age groups, while there were no significant differences among age groups 40–70 years old.

Reference values for hand grip strength, muscle mass, walking time, and one-leg standing time

Table 1 also shows the age-gender distribution of hand grip strength for both the better and worse sides. Mean hand grip strength in men was significantly higher than that in women ($p < 0.001$) and decreased with age in both men and women ($p < 0.001$).

Mean muscle mass for both forearms, both upper arms, both upper limbs, both quadriceps, both thighs, both lower legs, and both lower limbs are shown in Table 2. Muscle masses for all parts of the body were significantly higher in men than in women ($p < 0.001$). Mean muscle mass in men decreased with age for all areas except the lower leg. Particularly in the quadriceps and thighs, muscle masses in men aged ≥70 were significantly lower than those in their 40s–50s ($p < 0.05$). By contrast, although muscle mass for women aged ≥80 and older tended to be lower than those of younger age groups (other than the lower legs), there

**Table 1** Mean values (standard deviation) of anthropometric measurements and hand grip strength of the participants classified by sex and gender

| Age strata (years) | Number of subjects | Weight (kg) | Height (cm) | Body mass index ($g/cm^2$) | Grip strength (better side) (kg) | Grip strength (worse side) (kg) |
|---|---|---|---|---|---|---|
| Men | | | | | | |
| 40–49 | 32 | 73.5 (10.2) | 170.3 (7.3) | 25.4 (3.6) | 49.5 (8.2) | 49.3 (8.4) |
| 50–59 | 100 | 68.8 (10.6) | 168.0 (5.2) | 24.3 (3.3) | 47.3 (7.0) | 42.6 (6.9) |
| 60–69 | 137 | 65.4 (11.1)[a] | 165.2 (6.2)[a,b] | 23.9 (3.5) | 41.4 (6.6)[a,b] | 36.9 (7.9)[a,b] |
| 70–79 | 308 | 60.0 (8.1)[a,b,c] | 161.1 (5.7)[a,b,c] | 23.1 (2.7)[a,b] | 35.4 (6.8)[a,b,c] | 31.5 (7.1)[a,b,c] |
| 80 and older | 249 | 57.2 (8.9)[a,b,c,d] | 159.7 (6.0)[a,b,c] | 22.4 (2.9)[a,b,c] | 29.7 (6.2)[a,b,c,d] | 26.3 (6.3)[a,b,c,d] |
| Total | 826 | 61.6 (10.3) | 162.5 (6.7) | 23.3 (3.1) | 36.6 (9.1) | 32.7 (9.1) |
| Women | | | | | | |
| 40–49 | 93 | 55.9 (9.5) | 157.0 (4.4) | 22.6 (3.5) | 31.2 (4.3) | 28.2 (4.4) |
| 50–59 | 191 | 55.3 (8.9) | 154.4 (5.8)[a] | 23.2 (3.7) | 28.7 (4.9)[a] | 25.4 (4.9)[a] |
| 60–69 | 316 | 54.2 (8.0) | 152.0 (5.5)[a,b] | 23.4 (3.2) | 26.6 (4.3)[a,b] | 23.77 (4.5)[a,b] |
| 70–79 | 599 | 51.3 (8.5)[a,b,c] | 148.4 (5.9)[a,b,c] | 23.3 (3.5) | 22.6 (4.6)[a,b,c] | 19.7 (4.7)[a,b,c] |
| 80 and older | 443 | 47.4 (8.3)[a,b,c,d] | 145.5 (5.9)[a,b,c,d] | 22.4 (3.6)[c,d] | 19.4 (4.4)[a,b,c,d] | 16.6 (4.6)[a,b,c,d] |
| Total | 1,642 | 51.6 (8.9) | 149.5 (6.7) | 23.0 (3.5) | 23.7 (5.8) | 20.8 (5.8) |

[a] Significantly different ($p < 0.05$) from values of the age group in their 40s

[b] Significantly different ($p < 0.05$) from values of the age group in their 50s

[c] Significantly different ($p < 0.05$) from values of the age group in their 60s

[d] Significantly different ($p < 0.05$) from values of the age group in their 70s

**Table 2** Mean values (standard deviation) of segmental muscle mass (kg) in total right and left sides classified by age and gender

| Age strata (years) | Number of subjects | Forearm | Upper arm | Upper limb | Quadriceps | Thigh | Lower leg | Lower limb |
|---|---|---|---|---|---|---|---|---|
| Men | | | | | | | | |
| 40–49 | 25 | 1.20 (0.19) | 1.59 (0.36) | 2.79 (0.54) | 3.91 (0.64) | 7.76 (1.19) | 3.41 (0.66) | 11.16 (1.69) |
| 50–59 | 60 | 1.18 (0.16) | 1.53 (0.28) | 2.71 (0.41) | 3.73 (0.64) | 7.45 (1.22) | 3.41 (0.66) | 10.86 (1.60) |
| 60–69 | 67 | 1.15 (0.17) | 1.50 (0.28) | 2.65 (0.42) | 3.50 (0.68) | 7.02 (1.28) | 3.52 (0.86) | 10.54 (1.89) |
| 70–79 | 66 | 1.17 (0.20) | 1.43 (0.28) | 2.60 (0.46) | 3.37 (0.66)[a] | 6.78 (1.26)[a] | 3.51 (0.68) | 10.29 (1.70) |
| 80 and older | 30 | 1.11 (0.17) | 1.37 (0.26) | 2.48 (0.38) | 3.10 (0.62)[a,b] | 6.27 (1.18)[a,b] | 3.92 (1.11) | 10.18 (2.05) |
| Total | 248 | 1.16 (0.18) | 1.48 (0.29) | 2.65 (0.44) | 3.52 (0.69) | 7.04 (1.30) | 3.53 (0.80) | 10.57 (1.79) |
| Women | | | | | | | | |
| 40–49 | 67 | 0.77 (0.12) | 0.86 (0.19) | 1.63 (0.30) | 2.65 (0.60) | 5.37 (1.12) | 2.65 (0.47) | 8.02 (1.45) |
| 50–59 | 124 | 0.76 (0.10) | 0.82 (0.16) | 1.58 (0.24) | 2.56 (0.44) | 5.20 (0.82) | 2.58 (0.51) | 7.78 (1.20) |
| 60–69 | 161 | 0.78 (0.11) | 0.84 (0.16) | 1.62 (0.25) | 2.55 (0.45) | 5.18 (0.84) | 2.57 (0.42) | 7.74 (1.10) |
| 70–79 | 130 | 0.80 (0.12)[b] | 0.85 (0.16) | 1.66 (0.27) | 2.54 (0.46) | 5.17 (0.85) | 2.66 (0.53) | 7.83 (1.24) |
| 80 and older | 48 | 0.79 (0.43) | 0.82 (0.16) | 1.61 (0.28) | 2.39 (0.45) | 4.90 (0.84) | 2.91 (0.69)[b,c] | 7.81 (1.38) |
| Total | 530 | 0.78 (0.11) | 0.84 (0.16) | 1.62 (0.26) | 2.55 (0.47) | 5.18 (0.88) | 2.63 (0.51) | 7.81 (1.23) |

[a] Significantly different ($p < 0.05$) from values of the age group in their 40s

[b] Significantly different ($p < 0.05$) from values of the age group in their 50s

[c] Significantly different ($p < 0.05$) from values of the age group in their 60s

were no specific trends in muscle mass among age groups ≤79 years old. However, as for men, the muscle mass of the quadriceps in women tended to decline with age, although the difference was not statistically significant.

Mean 6-m walking time and the calculated walking speed (m/s) using the walking time, classified by age and gender, are shown in Table 3. Six-meter walking time was significantly lower in men than in women ($p < 0.05$), indicating that men tended to walk faster than women in this study population. Mean 6-m walking time for both men and women increased with age. In particular, 6-m walking times for men and women ≥70 years old were significantly higher than those in younger age groups ($p < 0.05$).

Table 4 shows median one-leg standing time classified by age and gender with 25th–75th percentile ranges. For both men and women in their 40s–50s, all median, 25th percentile, and 75th percentile values were 60 s, with no gender difference. One-leg standing times for men ≥60 years old tended to be higher than those for women, and median values declined with age in both men and women.

Prevalence of disability among subjects ≥65 years old

Among the 2,468 participants in the second visit of the ROAD study, we surveyed 1,845 subjects (625 men, 1,220 women) ≥65 years old and obtained information on the presence or absence of disability certified for long-term care insurance. We found a total of 149 individuals (8.1%; 36 men, 5.8%; 113 women, 9.3%) that were certified as requiring support. Figure 1 shows the prevalence of disability classified by gender and age. The prevalence of disability in men 65–69, 70–74, 75–79, and ≥80 years old was 0.0, 1.0, 6.3, and 8.8%, respectively, and that in women in the same age groups was 3.4, 3.5, 9.2, and 14.7%, respectively (Fig. 1). The prevalence of disability in women was significantly higher than that in men ($p < 0.05$) and increased with age in both genders ($p < 0.01$).

Associations between disability and hand grip strength, muscle mass, walking speed, and one-leg standing time

Logistic regression analysis was performed using the presence of disability (1, yes; 0, no) as an objective factor, and hand grip strength on the better side and the worse side; muscle mass of the forearms, upper arms, upper limbs, quadriceps, thighs, lower legs, and lower limbs; walking time for 6 m at the usual pace and at the fastest pace; and quartile of one-leg standing time [0: 0–25% (highest quartile), 1: 25–50% (higher quartile), 2: 50–75% (lower quartile), 3: 75–100% (the lowest quartile] on the better and worse sides as explanatory factors, after adjusting for age, gender, and BMI. No significant associations were found between the presence of disability and hand grip strength, muscle mass, or one-leg standing time. However, there were significant associations between the presence of disability and 6-m walking time at the usual