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Research article

Site-Specific Muscle Loss in the Abdomen and Anterior Thigh in Elderly Males with Locomotive Syndrome

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Abstract

Although locomotive syndrome (LS) is a condition of reduced mobility, little information is available regarding the loss of site-specific skeletal muscle mass. The aim of the present study is to examine site-specific muscle loss in elderly males with LS. A total of 100 men ranging in age from 65 to 74 years were divided into two groups (LS and non-LS) using LS risk tests including the stand-up test, two-step test, and the 25-question geriatric locomotive function scale Muscle thickness (MTH) at eight sites—anterior and posterior thigh (AT and PT, respectively), anterior and posterior lower leg (AL and PL, respectively), rectus abdominis (RA), anterior and posterior upper arm (AU and PU, respectively), and anterior forearm (AF)—was evaluated using B-mode ultrasound. Furthermore, the 30-s chair stand test (CS-30), 10-m walking time, zig-zag walking time, and sit-up test were assessed as physical functions. There were no significant differences in age and body mass index between the LS and non-LS groups. The percentage of skeletal muscle was lower in the LS group than in the non-LS group. Although there were no differences in the MTH of AU, PU, AF, PT, Al and PL, site-specific muscle loss was observed at RA and AT in the LS group. CS-30, 10-m walking time, zig-zag walking time, and sit-up test in the LS group were all worse than those in the non-LS group. The MTHs of RA and AT were both correlated to those physical functions. In conclusion, the LS group had site-specific muscle loss and worse physical functions. This study suggests that site-specific changes may be associated with age-related physical functions. These results may suggest what the essential characteristics of LS are.

Key words: Mobility, elderly, geriatric locomotive function, muscle thickness, physical function.

Introduction

Japan has one of the longest life expectancies in the world, and the Japanese population is aging rapidly. By 2055, it is projected that the elderly people over 65 years old will account for 40.5% of Japan's total population (Nakamura 2011). The concept of locomotive syndrome (LS) was proposed by the Japanese Orthopedic Association (JOA) in 2007, which described that problems with the locomotive organs such as skeletal muscles, joints, and bones (Nakamura and Ogata, 2016) predispose middle-aged and elderly individuals to a high risk of either requiring nursing care or becoming bedridden.

Methods of evaluating and assessing the risk of LS have been established by the JOA, and include three functional tests: the stand-up test, the two-step test, and the 25-question geriatric locomotive function scale (GLFS-25). Yoshimura et al. examined the association between these LS risk tests and a decline in mobility and demonstrated that these three LS risk tests predict immobility and an increased risk of LS (Yoshimura et al., 2015) and therefore reflect physical functions relevant to locomotion. Moreover, recent evidence has demonstrated that elderly people with LS have less muscle power in their lower limbs, and a shorter walking stride under maximum effort (Uesugi et al, 2020). These findings reflect difficulties in the ability to stand, walk, and perform other movements essential to daily life.

Excessive loss relevant to aging of skeletal muscle mass and muscle strength and physical functions, termed sarcopenia, is widely considered to be a cause of physical disability (Baumgartner et al., 1998; Chen et al., 2020). A low muscle mass index value has been used as a diagnostic criterion for sarcopenia. By contrast, LS has been mainly assessed by focusing on lower muscle functions with LS risk tests. Hence skeletal muscle mass is not considered in the assessment of LS. However, a study has demonstrated that site-specific muscle loss has an adverse effect on physical function (Abe et al, 2012), and it is therefore important to elucidate whether site-specific muscle loss also occurs in elderly people with LS. Unfortunately, there is currently limited information available for evaluating site-specific muscle loss in elderly individuals with LS. Moreover, in persons with LS, the relationship between site-specific muscle mass and the ability to perform physical functions is not fully understood.

The aim of the present study was to examine the site-specific loss of skeletal muscle in elderly males with LS. With regard to the prevention and improvement of LS,

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it is important to determine the differences in muscle mass between the elderly with LS and those without LS.

Methods

Participants

A total of 100 community-dwelling elderly males ranging in age from 65 to 74 years were included in this study. All participants were recruited through printed media, such as recruitment flyers or posters that were distributed or displayed in community or public facilities. Elderly people ranging in age from 65 to 74 years are defined as early elderly in Japan. The prevalence rate of LS in males gradually increases from the 60s (Tokida et al., 2020). For these reasons, elderly males ranging in age from 65 to 74 years were enrolled in this study. None of the participants had taken part in any regular high-intensity resistance exercise for at least 1 year. All the participants had no overt chronic diseases, which was verified by careful medical history assessments. All participants were informed about the methods, procedures, and risks associated with the study and provided informed consent before enrolment. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee for Human Experiments of Juntendo University (Approval Number: 27-10).

Assessment of locomotive syndrome

LS was evaluated using the LS risk tests, namely the two-step test, the stand-up test, and GLFS-25. The participants were classified as having LS if they fulfilled one or more of the following criteria: (1) difficulty in standing from a seat at a height of 40 cm using one leg in the stand-up test (either leg), (2) a two-step test score < 1.3, and (3) a GLFS-25 score ≥ 7 (Nakamura and Ogata, 2016). These criteria were used to divide the participants into LS and non-LS groups (Table 1). The medical histories of the participants are shown in Table 2.

Table 1. Values of locomotive syndrome risk tests in the non-LS and LS groups (mean ± standard deviation).

	non-LS (n = 58)	LS (n =42)	Δ%	P value
Stand-up test (score)	5.2 ± 0.4	3.8 ± 0.9	-36.8	<0.001
Two-step test (cm/cm)	1.48 ± 0.10	1.36 ± 0.11	-8.8	<0.001
GLFS-25 (score)	1.8 ± 1.7	4.4 ± 5.4	59.1	<0.001

non-LS: elderly males without locomotive syndrome; LS: elderly males with locomotive syndrome; GLFS-25: 25-question geriatric locomotive function scale; Δ%: percentage difference between non-LS and LS groups.

Table 2. Participants' medical history in the non-LS and LS groups [n (%)].

	non-LS	LS
Hypertension	21 (36)	16 (38)
Hyperlipidemia	8 (14)	19 (45)
Heart disease	6 (10)	2 (5)
Diabetes	7 (12)	4 (10)
Respiratory disease	13 (22)	2 (5)
Cataract	4 (7)	6 (14)
Liver disease	2 (3)	2 (5)
Cancer	4 (7)	4 (10)
Arthralgia	13 (22)	12 (29)

non-LS; elderly males without locomotive syndrome; LS: elderly males with locomotive syndrome.

Stand-up test

The stand-up test assesses the leg strength by instructing the participants to stand up either on one or both legs from four sets of different heights (40, 30, 20, and 10 cm). Participants were instructed to stand up without leaning back to gain momentum and to maintain their posture for 3 s. If the participant was unable to stand on one leg (right or left) from a height of 40 cm, then they were challenged stand on both legs. A score of 0–8 was allocated to the performance as described by Ogata et al (Ogata et al., 2015).

Two-step test

The participants stood with the toes of both feet behind a starting line. They then took two long steps (as long as possible) and aligned both feet. The length of the two steps from the starting line to the tips of the toes was measured. The two-step test score was calculated using the following formula: length of the two steps (cm)/height (cm). The measurements were repeated twice for both legs of each participant, and the higher score was used.

25-Question geriatric locomotive function scale (GLFS-25)

This questionnaire evaluated whether participants experienced any pain or had difficulties of daily living over the past month and included questions regarding pain (4 questions), activities of daily living (16 questions), social functions (3 questions), and mental health status (2 questions). Each item was graded on a five-point scale, from no impairment (0 points) to severe impairment (4 points) (Seichi et al., 2012). The sum of all the scores was considered as the degree of LS. Participants with a GLFS-25 score greater than 7 points were diagnosed with LS.

Body composition

Body weight, skeletal muscle mass, fat mass, and percentage body fat (% fat) were measured by bioelectrical impedance analysis (BIA) using a body composition analyzer (Inbody 730, InBody, Korea). This system also uses an electrical current at multiple frequencies to determine the amount of extracellular and intracellular water. The participants stood on four metallic electrodes whilst holding metallic grip electrodes. Test–retest (inter-session) reliabilities were calculated using the intraclass correlation coefficient (ICC), standard errors of measurement (SEM), and minimal difference. The ICC, SEM, and minimal difference for skeletal muscle mass and body fat mass were determined in 10 older men and women: skeletal muscle mass: 0.996, 1.18 kg, 3.28 kg body fat mass: 0.988, 2.37 kg, 6.57 kg, respectively.

Measurement of muscle thickness

Muscle thickness (MTH) was measured with B-mode ultrasound using a 5-18 MHz scanning head (Noblus; Hitachi, Tokyo, Japan) at eight locations as follows: the anterior and posterior aspects of the right thigh (AT and PT, respectively) at 50% of the thigh's length between the lateral condyle of the femur and the greater trochanter, the anterior and posterior aspects of the right lower leg (AL and PL, respectively) at 30% of the lower leg's length between the lateral malleolus of the fibula and the lateral

condyle of the tibia, the rectus abdominis (RA) at the level of the navel, the anterior and posterior aspects of the right upper arm (AU and PU, respectively) at 60% of the upper arm length between the acromion and the cracks of the lateral epicondyle of the humerus and radial head, and anterior aspects of the right forearm (AF) at 30% of the forearm length, between the cracks of the lateral epicondyle of the humerus and the radial head and the styloid process of the radius (Ozaki et al., 2020). All measurements were performed with the participant in the supine or prone position. The scanning head was coated with a water-soluble transmission gel and placed on each measurement site without depressing the dermal surface. The subcutaneous adipose tissue-muscle interface and muscle-bone interfaces were identified on ultrasound images, and the distance between the two interfaces was recorded as the MTH. The ICC, SEM, and minimal difference for MT were determined at eight locations as follows: AU: 0.986, 0.39 mm, 1.08 mm; PU: 0.998, 0.15 mm, 0.42 mm; AF: 0.987, 0.28 mm, 0.78 mm; RA: 0.998, 0.09 mm, 0.25 mm; AT: 0.992, 0.37 mm, 1.03 mm; PT: 0.994, 0.37 mm, 1.03 mm; AL: 0.993, 0.21 mm, 0.58 mm; PL: 0.998, 0.22 mm, 0.61 mm.

Evaluation of physical functions

30-s chair stand test (CS-30)

The participants were asked to sit on a 40 cm stool with both arms crossed against the chest. The participant was instructed to stand up when the participant's bottom touched the stool. The test was started from a sitting position and the participant repeatedly stood up and sat down. The number of times the activity was completed in 30 s was counted using a digital counter (T.K.K.5805, Takei Co, Niigata, Japan). The test-retest (intersession) reliabilities of the CS-30 using the ICC, SEM, and minimal difference were 0.779, 1.14 repetitions, and 3.17 repetitions, respectively.

Sit-up test

The participants lay on a flat surface with the knee bent at ~90° (0° = knee full extension) and with both arms crossed against the chest throughout the test. The participants were asked to raise the upper body until the crossed arms touched the front of the thighs and return to the floor. The number of times the activity was completed in 30 s was recorded. The test-retest (intersession) reliabilities of the sit-up test using the ICC, SEM, and minimal difference were 0.986, 2.63 repetitions, and 7.29 repetitions, respectively.

10-m walking time

The participants walked a 10-m straight course twice on a hard-surface floor as fast as possible without running. To exclude acceleration and deceleration phase during the 10-m walking test, at least 2 meters of space was provided at the start and finish line. The walking times were measured using a digital counter (T.K.K.5801, Takei Co, Niigata, Japan), and the best time was used in the data analysis. The test-retest (intersession) reliabilities of the 10-m walking time using the ICC, SEM, and minimal difference were 0.833, 0.20 s, and 0.57 s, respectively.

Zig-zag walking time

Zig-zag walking time was measured using a 10-m walkway. Four cones were placed on the floor (2 m apart) between the start and finish positions. A line was drawn from the start to the finish point and the cones were set to alternate from side to side at a specific distance (0.5 m) from the line. Participants were asked to walk as quickly as possible around the outside of each cone and through to the finish point. The time taken for the participant to pass the start and finish point was recorded using a digital counter (T.K.K.5801, Takei Co, Niigata, Japan). The best time of two trials was used as the zig-zag walking time. The test-retest (intersession) reliabilities of the zig-zag walking time using the ICC, SEM, and minimal difference were 0.865, 0.29 s, and 0.81 s, respectively.

Statistical analysis

All data are expressed as mean values ± standard deviations. All variables were checked for normality and analyzed using the unpaired student t-test. All analyses were performed using SPSS version 22.0. Relationships between site-specific MTH and physical functions were evaluated with Pearson's correlation coefficients. The statistical significance level was set as at $p < 0.05$.

Results

Demographics of participants

The demographics of the participants are shown in Table 3. There was no significant difference in age and BMI between the LS and non-LS groups. The percentage of skeletal muscle mass in the LS group was lower than that in the non-LS group. However, there were no significant differences observed between the LS and non-LS groups with respect to body fat mass and percentage of body fat.

Muscle thickness

The differences in MTH are shown in Table 4. The MTHs of RA and AT were lower in the LS group than those in the non-LS group. However, the MTHs of other parts (AU, PU, AF, PT, AL, and PL) did not differ between the groups.

Physical functions

The differences in physical function are shown in Table 5. All physical functions were lower in the LS group than those in the non-LS group.

Correlation between MTH and physical function tests

Pearson's correlation coefficients between MTH and physical functions are shown in Table 6. MTHs of RA and AT were positively correlated with the CS-30 (RA, $r = 0.291$, $p < 0.01$; AT, $r = 0.312$, $p < 0.01$), sit-up test (RA, $r = 0.597$, $p < 0.001$; AT, $r = 0.407$, $p < 0.001$). MTHs of RA and AT were inversely correlated with both the 10-m walking time (RA, $r = -0.221$, $p < 0.05$; AT, $r = -0.372$, $p < 0.01$) and the zig-zag walking time (RA, $r = -0.226$, $p < 0.05$; AT, $r = -0.292$, $p < 0.05$).

Table 3. Characteristics of participants between the non-LS and LS groups (mean ± standard deviation).

	non-LS	LS	Δ%	P value
Age (years)	69.0 ± 3.0	69.0 ± 2.8	0.0	0.926
Stature (m)	1.65 ± 0.05	1.68 ± 0.06	1.8	0.004
Body mass (kg)	62.5 ± 8.0	67.2 ± 9.1	7.0	0.007
Body mass index (kg/m2)	23.1 ± 2.3	23.6 ± 3.6	2.1	0.388
Skeletal muscle mass (kg)	27.0 ± 3.1	27.8 ± 3.1	2.9	0.158
Percentage of skeletal muscle mass (%)	43.3 ± 2.9	41.9 ± 3.7	-3.3	0.032
Body fat mass (kg)	14.0 ± 4.3	15.5 ± 5.5	9.7	0.142
Percentage of body fat (%)	21.7 ± 5.1	22.4 ± 5.7	3.1	0.551

non-LS: elderly males without locomotive syndrome: LS: elderly males with locomotive syndrome; Δ%: percentage difference between non-LS and LS groups.

Table 4. Differences in MTH between the non-LS and LS groups (mean ± standard deviation).

	non-LS	LS	Δ%	P value
AU (mm)	28.7 ± 2.7	28.3 ± 2.6	-1.4	0.514
PU (mm)	22.9 ± 4.5	22.7 ± 5.5	-0.9	0.268
AF (mm)	18.9 ± 2.2	19.1 ± 2.4	1.0	0.685
RA (mm)	11.8 ± 2.1	10.2 ± 1.7	-15.7	0.001
AT (mm)	31.8 ± 4.5	28.4 ± 3.8	-12.0	0.001
PT (mm)	53.5 ± 5.0	54.1 ± 5.0	1.1	0.516
AL (mm)	25.3 ± 2.6	25.3 ± 3.0	0.0	0.944
PL (mm)	61.3 ± 4.8	61.1 ± 5.6	-0.3	0.863

non-LS: elderly males without locomotive syndrome; LS: elderly males with locomotive syndrome; Δ%: percentage difference between non-LS and LS groups; AU: anterior aspect of the upper arm; PU: posterior aspect of the upper arm; AF: anterior aspect of the forearm; RA: rectus abdominis; AT: anterior aspect of the thigh, PT; posterior aspect of the thigh, AL; anterior aspect of the lower leg; PL: posterior aspect of the lower leg.

Table 5. Differences in physical functions between the non-LS and LS groups (mean ± standard deviation).

	non-LS	LS	Δ%	P value
CS-30 (repetitions)	24.7 ± 5.3	20.6 ± 4.8	-19.9	<0.001
Sit up test (repetitions)	19.5 ± 4.7	13.3 ± 5.8	-46.6	<0.001
10m walking time (s)	4.5 ± 0.7	5.2 ± 0.7	13.5	<0.001
Zig-zag walking time (s)	6.1 ± 0.9	6.7 ± 1.0	9.0	<0.001

non-LS: elderly males without locomotive syndrome; LS: elderly males with locomotive syndrome; Δ%: percentage difference between non-LS and LS groups.

Table 6. Pearson's correlation coefficients between the MTH of AT and RA and physical functions.

	CS-30 (repetitions)	Sit up test (repetitions)	10 m walking time (s)	Zig-zag walking time (s)
RA (mm)	0.291 **	0.597 ***	-0.221 *	-0.226 *
AT (mm)	0.312 **	0.407 ***	-0.372 **	-0.292 *

RA: Rectus abdominis: AT: anterior aspect of the thigh; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

Discussion

This study investigated whether site-specific muscle loss was observed in elderly males with LS. The results showed site-specific muscle loss in the RA and AT in elderly males with LS. Moreover, the reduction in site-specific muscle mass significantly correlated to LS-related physical functions. These results may suggest what the essential characteristics of LS are. It is known that site-specific muscle mass loss caused by aging precedes whole-body muscle mass loss.

The MTH of the AT was significantly lower in elderly persons with LS. Ohsawa et al. reported a trend toward reduced muscle mass in the lower leg (measured by BIA) in the elderly with LS compared to those without LS, although it was not significant ($p = 0.056$) (Ohsawa et al., 2016). However, no studies have focused on the site-specific changes in muscle mass in LS. Therefore, this is the first study in which the occurrence of site-specific muscle loss of the AT in elderly males with LS was observed. The MTH of the AT in this study only included the rectus femoris and vastus intermedius muscles. However, the MTH of the AT is a valid index of the quadriceps muscle cross-sectional area (CSA), because it correlates highly with the quadriceps CSA (r=0.91) (Abe et al.,1997). Coordinated contraction of the quadriceps muscle causes hip flexion and/or knee extension. Knee extension moments are required in order to stand up from a sitting position (Yoshioka et al., 2014). In addition, knee extension and hip flexion moments contribute to an increase in walking speed and stride length (McGarth et al., 2019; Ardestani et al., 2016). Given that the MTH correlates with muscle strength (Nishihara et al., 2018), the decline on the knee and hip joint moments induced by the site-specific muscle loss in the AT may adversely affect physical functions (CS-30 and walking speed) and LS risk tests (stand-up tests and 2-step test) in elderly individuals. However, causal relationships were not clearly established because we performed a cross-sectional study. Moreover, as reported in a study by Santos et al., improvement of the lower limb muscular strength following 8 weeks of resistance training was associated with physical function (walking speed) in elderly people, but not lower skeletal muscle mass in older females (Santos et al., 2017). Therefore, a future longitudinal study is

required to elucidate causal relationships among these factors in older males with LS.

In addition to the site-related difference in limb muscle, this study also provided evidence that like the TA, the muscle located in the trunk region, especially in the abdomen, influences physical functions. Previous studies have shown the site-specific reduction in abdominal muscle with age (Miyatani et al., 2003; Fukumoto et al., 2015). However, whether the size of the abdominal muscle decreases in the elderly with LS was unknown. Site-specific muscle loss in the abdomen may influence the decrease in the locomotive function in the elderly. Indeed, the superficial trunk muscles recruit in concert with the deep muscle and are thought to contribute to the efficient transfer to the body's center of mass (Crenna et al., 1987; Frank and Earl, 1990), maintenance of lumbo-pelvic equilibrium (Hodges et al., 1999), and the absorption of reaction forces associated with ground contact events (Iida et al., 2011; Jonsson, 1970). Moreover, our study showing that the site-specific muscle loss in the RA, which is the superficial trunk muscle, not only correlated with the sit-up test, but also with the 10-m walking time and is therefore relevant to locomotion. Our results agree with the previous studies that demonstrated a relationship between the CSA of the RA and the 6 min walk test in elderly persons (Saunders et al., 2004; Shahtahmassebi et al., 2017). Given that it has been observed that the abdominal muscles are gradually recruited during increasing locomotion speed (Saunders et al., 2004; 2005), the muscle would therefore contribute to high-speed locomotion. These results imply that the preservation of the trunk muscle size may also be an important factor to prevent LS. From the practical aspects, exercises using the AT and abdominal muscles may help in prevention and improvement of LS.

The decline in hormone levels such as testosterone in the aging male are expected to have adverse effects for locomotive organs including the skeletal muscle (Fink et al., 2020). Previous studies have reported that a greater amount of physical activity is associated with a higher level of testosterone concentration (Shiels et al., 2009; Muller et al., 2003). Our pilot study investigated the difference in daily physical activity between elderly people with and without LS using an accelerometer and found that elderly people with LS have lower daily physical activity compared to elderly people without LS (Ishihara et al., 2016). Therefore, the interrelationship between physical activity in daily life and etiologic factors may contribute to a decrease in muscle mass. However, it is difficult to discern the mechanism behind the site-specific muscle loss in male elderly people.

This study had several limitations. First, participants were limited to men aged 65–74 years. It is unclear whether a similar trend would be observed in males over 75 years, and in elderly females. Second, the prevalence of LS in this study (42%) was lower than that in a previous study, which reported that the prevalence in the 60–70 years age group is approximately 67–85% (Yoshimura et al, 2015). Third, as described above, we could not refer to the causal relationships between the site-specific muscle loss of AT and RA and physical functions because of the cross-sectional study design. Fourth, the number of people recruited in this study was limited. Therefore, a future follow-up study is required to clarify the causal relationships among these factors.

Conclusion

In conclusion, we found site-specific muscle loss in the AT and RA, and poor physical function in elderly males with LS. This study suggests that the decline of site-specific muscle may be associated with age-related physical functions. These results may suggest what the essential characteristics of LS are.

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Key points

- Locomotive syndrome related muscle loss was observed in the anterior thigh and rectus abdominis muscle in elderly males.
- The elderly males with locomotive syndrome had lower physical functions (30-s chair stand test, 10-m walking time, zig-zag walking time, and sit-up test).
- Site-specific muscle loss in elderly males with locomotive syndrome suggest age-related decline in physical functions.

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