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ORIGINAL ARTICLE

Natural aging course of lumbar extensor muscle mass and strength in community-dwelling older women: a 1-year prospective observational study

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Abstract

Background Although the loss of skeletal limb muscle mass and muscle strength in the elderly have been demonstrated, the aging process of the back muscles to maintain core stability is not well known. This 1-year prospective observational study aimed to investigate the natural aging course of the lumbar extensor muscles (LEMs) compared with the extremity muscles and determine whether muscle strength or mass decreases more in community-dwelling older women.

Methods Twenty-four older urban-dwelling women aged 70 years or older were initially enrolled. Their demographic variables, conventional and spinal sarcopenia indices, and functional outcome parameters were evaluated. We also measured back extensor strength, radiological parameters for spinal sagittal balance on whole-spine radiography, and volumetric parameters of the LEM on computed tomography.

Results After the exclusion of 6 subjects, 18 older women were finally analyzed. All variables related to extremity muscle mass, muscle strength, physical performance, and LEM volume declined over the study period, but the changes were insignificant. However, back extensor strength decreased significantly (median, first, and third quartile: 35.20 [30.80, 44.00] N to 31.40 [29.25, 37.90] N, $P=0.026$). Among spinal sagittal balance-related parameters, lumbar lordosis (44.25 [39.30, 47.35]° to 43.15 [31.43, 45.75]°, $P=0.043$) and sagittal vertical axis (33.85 [3.57, 58.75] mm to 45.15 [25.35, 58.68] mm, $P=0.004$) showed significant changes during the study.

Conclusions When the natural aging course of LEM in women aged 70 years or older was observed for 1 year, muscle mass decreased less than back extensor strength and spinal sagittal balance. Measurements of back extensor strength and spinal sagittal balance are necessary for the clinical evaluation of spinal aging.

Keywords Lumbosacral region · Paraspinal muscles · Sarcopenia · Spine

Background

Sarcopenia is the loss of skeletal muscle due to the natural aging process [1]. It is a syndrome characterized by progressive and generalized loss of skeletal muscle mass and strength [2]. The primary mechanisms of sarcopenia include muscle protein turnover alterations, muscle tissue remodeling, alpha motor neuron loss, and muscle cell recruitment and apoptosis [3]. The secondary mechanisms of sarcopenia include physical inactivity, inadequate nutrition, hormonal dysfunction, and insulin resistance [2, 4]. These various mechanisms interact complexly to create the syndrome called sarcopenia.

The spine is an inevitable site of sarcopenia due to the large muscles surrounding it. Sarcopenia of the lumbar paraspinal muscles has been investigated as a cause of

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spinal degeneration. Both atrophy and fatty degeneration in the muscles originating from sarcopenia are associated with functional disorders and chronic back pain [5]. However, conventional diagnostic measurements of sarcopenia—appendicular skeletal muscle mass (ASM), handgrip strength (HGS), and gait speed—cannot reflect sarcopenia of the spinal region and its clinical outcomes because they focus on the extremity muscles [6].

A 30% reduction in muscle mass occurs from 20 to 80 years of age [7] due to decreases in muscle fiber size and number [8]. A 12-year longitudinal study reported a 12.5–16.1% reduction in thigh muscle cross-sectional area and a 23.7–29.8% decrease in muscle strength of the knee extensors and flexors in 12 healthy sedentary men [7]. The Health, Aging and Body Composition Study suggested that aging is associated with a greater decline in lower body than upper body strength and in extensor versus flexor strength [9]. However, it has not yet been studied whether the muscles of the trunk or extremities decrease greater with aging. In addition, among the trunk muscles, aging-related changes in lumbar extensor muscles (LEMs) associated with spinal degeneration should be investigated.

LEM degeneration can be a cause of spinal sagittal imbalance. One study suggested that the estimated LEM volume measured by magnetic resonance image is related to sagittal curvature magnitude [10]. Masaki et al. also reported that spinal sagittal alignments associated with not only lumbar back muscle quantity but also muscle quality [11]. Thus, spinal sagittal balance measurement should be included to investigate LEM sarcopenia.

This 1-year prospective observational study aimed to investigate the natural aging course of the LEMs versus the extremity muscles in community-dwelling older women. We also aimed to determine whether muscle strength or muscle mass decreases greater in the population and whether these trends differed between the LEMs and extremity muscles.

Methods

Study population

This was a prospective 1-year follow-up study of a baseline study [12] that enrolled healthy community-dwelling older (≥ 70 years) women who could independently walk more than 100 m in a single center. A 1-year follow-up was conducted from July to December 2019. Exclusion criteria were applied as in the previous study [12]. Demographic data and findings of a sarcopenia workup, various functional examinations and questionnaires, and spinal imaging (X-ray and computed tomography [CT]) were collected using the same protocol as in the baseline study as described in detail below. All methods were carried out in accordance with the Declaration of Helsinki and the Institutional Review Board of SMG-SNU Boramae Medical Center (no. 16-2017-45) approved the study, and each participant provided written informed consent.

Sarcopenia workup

Bioelectric impedance analysis (BIA) (InBody 720; Biospace Co., Seoul, South Korea) was used to analyze each participant's body composition, including lean body and fat masses. ASM was calculated by obtaining the sum of the lean masses of the bilateral upper and lower extremities [13] and dividing the value by the height squared (ASM/Ht^2 [kg/m^2]). HGS was measured of both hands using a handgrip dynamometer (T.K.K.5401; Takei Scientific Instruments, Tokyo, Japan) [14] as described previously [15]. Briefly, participants were requested to adduct and neutrally rotate the shoulder, extend the elbow, and put the forearm in a supine posture with the wrist at 0–30° of extension and 0°–15° of ulnar deviation while sitting in a straight-backed chair with their feet level on the floor. The individuals were told to press the handle as hard as they could for 3 s, and the maximal contraction force (kg) was measured. The Asian Working Group for Sarcopenia advised that gait speed be assessed using a 6-m usual gait speed test (m/s) with a moving start, and the criteria and cutoffs for sarcopenia were also taken from their guidelines [16].

Functional examinations

The functional examination used the short physical performance battery derived from three objective physical function tests (i.e., time taken to cover 4 m at a comfortable walking speed, time taken to stand five times from sitting in a chair without stopping [chair stand test], and ability to maintain one's balance for 10 s in three different foot positions at progressively more challenging levels) [17]. A score of 0–4 was assigned to rate the performance of each task, with higher scores indicating better lower body function. The Timed Up and Go test has shown excellent test–retest reliability in older adults [18]. The participants were told to get out of an arm chair, walk 3 m as quickly as they could, turn around at a cone placed up by the researchers, walk back, and seat in the chair. They were permitted to wear their usual shoes and, if necessary, utilize a walking assistance. When the participant was fully situated with their back against the seat back, a stopwatch was started and stopped. The time it took the individuals to complete the exam was recorded for three attempts in a row, the first of which was used to familiarize them with the test. After then, the best time for each of the three trials was examined [19].

The back performance scale consists of the sock, pick-up, roll-up, fingertip-to-floor, and lift tests. These five tests

are associated with each other, and each contributes to its high internal consistency, implying that they share a common ability to measure physical performance [20]. By summing the individual results of the five tests, the cumulative score (0–15) is calculated. The Oswestry Disability Index, among the most commonly used instruments for measuring disability in spinal disorders, consists of 10 items that assess pain level and interference during several physical activities. The Korean version of the Oswestry Disability Index was employed in this study [21].

Measurement of isometric back extensor strength

The isometric back extensor strength was measured using a hand-held dynamometer (PowerTrack II; JTECH Medical, Salt Lake City, UT, USA) [22]. Briefly, each participant stood with their backs to the wall, feet level on the floor, and heels touching the wall at full extension. To constrain movement and maintain participant contact with the wall during the test, an inelastic belt was looped around the anchor rails and tightly attached 1 cm below the anterior superior iliac spine. The dynamometer was to be positioned posterior to the spinous process of the seventh thoracic vertebra, therefore, each participant was directed to bend forward at the hips around 15 degrees. The immovable wall behind the back produced counterpressure in this way, preventing the tester from introducing changes in resistance. This test shows a strong positive relationship with back extensor strength measured on the gold-standard isokinetic dynamometry as well as inter-instrument validity and reliability [23].

Measurement of spinal sagittal balance

For each patient, a lateral radiograph of the whole spine was obtained and digitized. All measurements were performed using imaging software (INFINITT PACS M6; INFINITT Healthcare, Seoul, South Korea) as previously described [24, 25]. Briefly, the following spinopelvic radiographic parameters were analyzed: lumbar lordosis, thoracic kyphosis, sagittal vertical axis, pelvic tilt, sacral slope, and pelvic incidence.

Three-dimensional measurements of lumbar extensor muscle by CT

To measure the real volume and signal intensity of the LEM, we used three-dimensional (3D) segmentation of the muscles. All participants were examined using a CT scanner (Revolution EVO; GE Medical Systems, Milwaukee, WI, USA). Before each CT scan, the scanner was calibrated using air as the standard. CT scanning was performed with each patient in the supine position following a routine lumbar CT scan protocol at 120 kV and 140 mA. Using 0.625-mm thin-section axial CT scan images, 3D volume rendering and multiplanar images were reformatted using a radiological workstation (MEDIP; MEDICALIP, Seoul, South Korea) especially designed for such purposes. We used a semiautomatic 3D segmentation algorithm, the graph-cut technique [26], for volumetric muscle segmentation with MEDIP. During the segmentation procedure, the experienced radiologist repeatedly modified and confirmed the segmentation results using the MEDIP.

The volume and mean density (in Hounsfield units [HU]) of the LEMs (multifidus and erector spinae) were calculated from the 3D segmentation. The total LEM volume, including intramuscular fat tissue, was measured by segmentation from the upper endplate of the first lumbar vertebra to the lower endplate of the fifth lumbar vertebra. The mean LEM density was also calculated as the average HU value of the pixels within the LEM volume and reflected the degree of intramuscular fat content because the HU values decreased as the fat content increased.

Statistical analysis

A paired mean comparison test was used to compare demographic data, sarcopenia-related characteristics, functional assessment and questionnaire findings, and spinal imaging outcomes before and after 1 year. Since the number of individuals was inadequate, the Wilcoxon signed-rank sum test was used to compare the means of all variables. All variables were described as median (first and third quartiles). SPSS Statistics version 21.0 for Windows (IBM Corp., Armonk, NY, USA) was used for all analyses. Statistical significance was set at $P < 0.05$.

Results

The median age of the participants was 76.0 (74.0, 79.0) years. At the baseline survey, 14 had possible sarcopenia, and none had sarcopenia among 25 subjects. After 1 year, 10 out of 18 participants had possible sarcopenia and 1 had sarcopenia. Twenty-four subjects were initially enrolled in the study. After six subjects were excluded from the 1-year follow-up study due to refusal to provide consent, 18 older women were ultimately analyzed. Among the anthropometric and sarcopenia-related variables, only mean height was significantly decreased over the 1-year period (149.75 [145.63, 154.95] cm to 149.05 [144.55, 154.03] cm, $P = 0.003$). Although both ASM and ASM/Ht^2 tended to decrease, these differences were not statistically significant. All variables related to muscle strength and physical performance showed functional declines over 1 year, but these were also insignificant (Table 1).

Table 1 Comparisons of outcome variables from baseline to 1-year follow-up

	N	Baseline [median (Q1–Q3)]	1-year F/U [median (Q1–Q3)]	*P* value
Anthropometric data				
Height (cm)	18	149.75 (145.63, 154.95)	149.05 (144.55, 154.03)	***0.003***
Weight (kg)	18	54.90 (52.18, 58.20)	54.40 (50.63, 57.78)	0.663
BMI (kg/m^2)	18	24.29 (23.12, 27.12)	24.33 (22.97, 27.12)	0.557
Sarcopenia indices				
ASM (kg)	13	14.20 (12.35, 14.77)	13.50 (12.08, 14.45)	0.087
ASM/Ht^2 (kg/m^2)	13	6.04 (5.77, 6.30)	5.83 (5.72, 6.35)	0.221
Handgrip strength (kg)	18	19.15 (16.53, 21.95)	19.05 (16.50, 24.23)	0.257
Gait speed (m/s)	18	0.87 (0.73, 0.99)	0.86 (0.76, 0.99)	0.983
Physical performance				
SPPB	18	11.50 (8.75, 12.00)	11.00 (9.00, 12.00)	0.855
Chair stand test (s)	18	21.10 (16.66, 28.59)	23.67 (16.65, 28.85)	0.879
Timed up and go (s)	18	8.83 (7.61, 9.64)	8.95 (8.29, 10.87)	0.267
Back strength and performance				
Back extensor strength (N)	18	35.20 (30.80, 44.00)	31.40 (29.25, 37.90)	***0.026***
Back performance scale	18	3.00 (2.00, 3.50)	3.50 (2.00, 5.00)	0.067
Oswestry Disability Index	18	7.50 (6.00, 9.50)	8.50 (4.50, 13.50)	0.943
LEM measure by CT				
LEM total volume (cc)	17	515.25 (443.63, 583.40)	505.23 (459.78, 586.01)	0.943
LEM signal intensity (HU)	17	18.67 (11.26, 25.07)	16.73 (12.66, 24.26)	0.102
Spinal sagittal balance				
Lumbar lordosis (°)	18	44.25 (39.30, 47.35)	43.15 (31.43, 45.75)	***0.043***
Thoracic kyphosis (°)	18	37.10 (29.98, 45.15)	38.00 (29.35, 46.83)	0.931
Sagittal vertical axis (mm)	18	33.85 (3.57, 58.75)	45.15 (25.35, 58.68)	***0.004***
Pelvic tilt (°)	18	22.50 (16.83, 27.98)	23.05 (18.35, 25.98)	0.647
Sacral slope (°)	18	40.05 (27.50, 43.73)	38.90 (27.33, 44.55)	0.542
Pelvic incidence (°)	18	53.90 (46.08, 61.08)	55.75 (50.08, 64.88)	0.068

P-value < 0.05 by Wilcoxon signed-rank sum test (in bolditalic)

ASM appendicular skeletal muscle mass, *Ht*^{2} height squared, *SPPB* short physical performance battery, *TUG* Timed Up and Go test, *LEM* lumbar extensor muscle

As for LEM mass analyzed by 3D segmentation of the lumbar spine CT scan, both LEM volume and signal intensity tended to decrease, but these changes were not significant. However, mean back extensor strength was significantly decreased (35.20 [30.80, 44.00] N to 31.40 [29.25, 37.90] N, $P = 0.026$). Among spinal sagittal balance-related parameters, lumbar lordosis was significantly decreased (44.25 [39.30, 47.35]° to 43.15 [31.43, 45.75]°, $P = 0.043$) and sagittal vertical axis was significantly increased (33.85 [3.57, 58.75] mm to 45.15 [25.35, 58.68] mm, $P = 0.004$) (Table 1).

According to the percentage change over 1 year for each variable, back extensor strength (− 14.81%) and lumbar lordosis angle (− 7.70%) decreased more than ASM/Ht^2 (− 1.17%), handgrip strength (− 0.36%), gait speed (− 2.30%), and LEM volume (− 0.17%) (Fig. 1).

Discussion

The most important finding of this 1-year study of women over 70 years of age was that the most sensitive variables were back extensor strength and lumbar lordosis angle among the variables about extremity and spinal muscles. As general sarcopenia indicators are limited to quantitative–qualitative evaluations of the extremity muscles, it is difficult to determine the degree of aging over 1 year. However, in this study, although no significant change in LEM mass was noted, we confirmed that the decreases in back

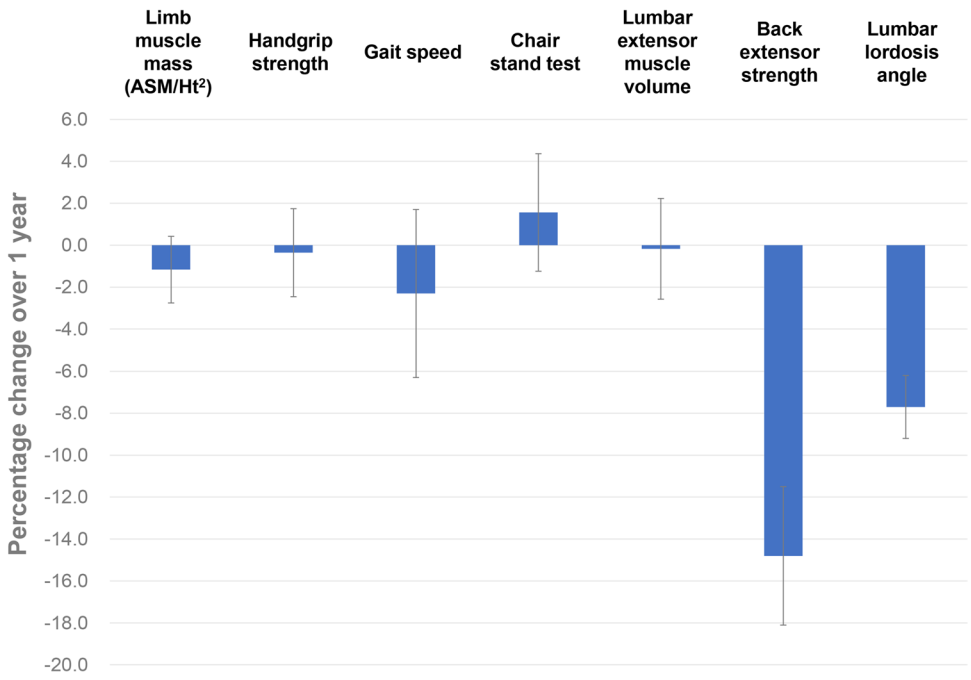

Fig. 1 Percentage changes for each variable about conventional and spinal sarcopenia over 1 year

extensor strength and lumbar lordosis angle proceeded more rapidly than the extremity muscle–based indices.

The 1-year loss of skeletal muscle mass in older women was approximately 1.1% in this study. This finding was similar for both ASM (1.17%) and LEM (1.09%). Similarly, one longitudinal study showed that muscle mass is lost at a rate of 0.64–0.7% per year in older women versus 0.8–0.98% per year in older men [27]. The lean mass of the thigh decreased by approximately 5% over the 5-year period in both men and women [28]. In a 12-year longitudinal study of nine men, Frontera et al. also reported a mean 14.7% decrease in quadriceps cross-sectional area (from 65 to 77 years) [7], a decrease of about 1.2% per year.

HGS, which was used to screen for and confirm sarcopenia [29], also showed a smaller decrease (0.36% per year) than that of muscle mass in this study. A population-based survey in Finland reported that the annual decrease in HGS in women prior to 45 years of age was approximately 2 N, while that after age 80 years was approximately 4 N per year [30]. Although muscle mass changes influenced the magnitude of the strength changes over time, strength declines despite muscle mass maintenance or even gain can occur due to other cellular, neural, or metabolic mediators [31]. Walking speed declines with age, and a slower walking speed has been associated with an increased risk of falls, hospitalizations, and subsequent physical and cognitive decline [32, 33]. A meaningful decline in usual walking speed was defined as a walking speed decrease of at least 0.05 m/s per year of follow-up [33, 34]. In this study, the mean decrease in walking speed over 1 year was 0.02 m/s (2.30%), although it was not meaningful since there was no statistically significant difference. However, compared to HGS, walking speed showed a much greater decrease, so it has clinical significance as an important tool for confirming deteriorations in muscle function and performance.

There are few studies on the natural aging of the muscles around the spine. Only two cross-sectional studies compared the trunk muscle strength of older versus young adults. Singh et al. reported that the estimated rate of decline of LEM isometric strength per decade from the sixth to eighth decades of life is approximately 40% and 81% in women and 21% and 41% in men [35]. One Japanese cohort study suggested that trunk muscle torque in one's eighties decreased by 60% compared with healthy young adults [36]. However, a longitudinal study of back muscle mass and strength as well as spinal sagittal balance has not yet been reported, and this study is the first attempt. In this study, back extensor strength and lumbar lordosis angle were more sensitive and significantly reduced than the classical variables for sarcopenia mentioned above. The back extensor strength showed the largest decrease at 14.80%, while the lumbar lordosis angle also decreased significantly over 1 year (7.70%). These two variables (back extensor strength and lumbar lordosis angle) can be considered the outcomes of muscle function around the spine. In addition, lumbar lordosis angle has the advantage that it can be measured relatively easily in clinical practice. This is because most studies that quantitatively evaluated spinal muscles have been attempted with muscle cross-sectional analysis based on CT or MRI [12, 37–40]. Therefore, we recommend measuring these variables to

check the aging and function of the muscles around the spine.

The back extensor muscle group, which mainly consists of the multifidus and erector spinae muscles, has predominant type I (slow twitch) muscle fibers [41]. This reflects the function of the back extensor muscle as a core stabilizer requiring a high level of endurance [42]. Since sarcopenia is mainly attributed to type II rather than type I muscle fibers, this muscle group was expected to be less susceptible to aging than the extremity muscles. In terms of muscle mass reduction, the decrease in the back extensor muscle mass (1.09%) was actually slightly less than that in the extremities (1.17%). However, in terms of muscle function, back extensor strength decreased faster than HGS and walking speed. The reason for this opposite trend can be explained by the decrease in lumbar lordosis (spinal sagittal imbalance), which was also confirmed in this study. When lumbar lordosis is reduced and the lumbar spine curves forward, the back extensor muscles require eccentric contraction. Since a decrease in lumbar lordosis may be a result or cause of a decrease in back extensor strength [12], it may have been further accelerated through the vicious cycle of this phenomenon. Furthermore, back extensor muscles are from a single muscle group while HGS and gait speed involve multiple muscle groups, which make HGS and walking more resistant to aging impacts. Although this study observed the older adults over 70 years for just 1 year, we could identify that the decrease in the aging of the back extensor muscles progressed greater than that of the extremity muscles.

There are several limitations to this study. First, the number of participants was small. Furthermore, there was a follow-up loss of 6 of 24 participants. Therefore, a larger sample size is required to generalize our results. Since we are conducting a larger community-based follow-up study [43], it may be possible to increase the statistical power in the future. Second, there must have been a difference in muscle mass measurements because the muscle mass of the extremities was measured by BIA while that of the LEM was based on CT imaging. Of course, since we did not directly compare the absolute muscle masses, we compared the annual degrees of change. The possible measurement of the back extensor muscles using lateral whole-body dual-energy X-ray absorptiometry was recently suggested [6], so it will be possible to compare limb and back muscles in this manner in a future study. Finally, low back pain itself can decrease spinal function and back extensor muscle mass. To minimize the effects of this low back pain, we recruited subjects with a low back pain visual analog scale score of 3 or lower. However, as confirmed in the 1-year follow-up, decreased lumbar lordosis may cause lower back pain, which may have decreased the back extensor muscle strength. Therefore, in future studies, it will be necessary to set the subjective scale of low back pain at a lower threshold to ensure subject eligibility.

Conclusions

This prospective study investigated the natural aging course of LEM in women aged 70 years or older for 1 year. Our findings noted greater decreases in back extensor strength and lumbar lordosis than in muscle mass. Thus, measurements of back extensor strength and spinal sagittal balance are necessary for the clinical evaluation of spinal aging.

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Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Statement of human and animal rights The study was conducted in accordance with the principles of the Declaration of Helsinki. Institutional Review Board of SMG-SNU Boramae Medical Center approved the study (no. 16-2017-45).

Informed consent Written informed consent was obtained from all subjects.

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