Postural Sway during Local Vibratory Stimulation for Proprioception in Elderly Individuals with Pre-Sarcopenia

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ABSTRACT. Objective: Many studies have demonstrated that the loss of muscle mass (LMM) poses a risk of postural instability in the elderly; however, few studies have shown how LMM decreases proprioception. In this study, we investigated the changes in postural sway among older individuals with LMM induced by application of a local vibratory stimulus. Method: We enrolled 64 older adults (mean age). Postural sway was measured while applying vibration stimuli of 30, 60, and 240 Hz to both the gastrocnemius and lumbar multifidus muscles. We also measured the relative proprioceptive weighting ratio (RPW) of postural sway. The patients were divided into LMM and non-LMM (NLMM) groups. The study subjects were compared in terms of their age, height, weight, body mass index (BMI), lower leg skeletal muscle mass index (LSMI), L4/5 lumbar multifidus cross-sectional area ratio, and RPW at 30, 60, and 240 Hz. Results: Subjects in the LMM group showed a significantly lower RPW at 60 Hz, LSMI, and BMI than did those in the NLMM group. Conclusions: Decrease in RPW with 60-Hz stimulation concerning the lower leg proprioception is a risk factor for LMM-associated postural instability in the elderly. Consequently, with respect to the gastrocnemius muscles proprioception in LMM, it is necessary to perform assessments using muscle spindle stimuli.

Key words: proprioception, skeletal muscle mass, lumbar spondylosis, muscle spindles

Loss of muscle mass (LMM) without affecting muscle strength is a characteristic of pre-sarcopenia1). It has been reported that proprioceptive control strategy is impaired in the elderly causing a decline in the postural balance2). Meanwhile, previous studies have reported that LMM is a factor contributing to postural instability3). Moreover, the proprioceptive input from the muscles in the legs and trunk plays an important role in maintaining postural stability4). A previous study showed that proprioception in the lower limbs decreased with age and was accompanied by postural instability in older individuals5). Therefore, in such individuals, we considered that skeletal muscle proprioceptive receptors are impaired and that vibrational stimuli that correspond to the response frequency may influence posture stability and trunk mobility.

The response frequencies of the representative proprioceptive receptors are 30 Hz in Meissner’s corpuscles, 60 Hz in muscle spindles, and 240 Hz in Vater-Pacini corpuscles6). However, the specific proprioceptors that cause the decline in muscle mass and postural sway in the elderly have not yet been clearly understood. Further, no studies have investigated the relationship of postural instability with proprioceptive decline and LMM.

Thus, the purpose of this study was to analyze the postural sway and LMM changes induced by the application of a local vibratory stimulus in the elderly by evaluating the proprioceptive dominance.
Method

1. Participant selection

This cross-sectional study was conducted over a period of 3 years and 4 months. Written informed consent was obtained from all participants before their inclusion in the study.

The criteria for the LMM and the non-LMM (NLMM) groups were based on previous research\(^7\). The cutoff value for pre-sarcopenia was defined based on data from Japanese and Gerontology approved the study (IRB approval number: Ethics Committee of the National Center for Geriatrics and Gerontology for volunteering purposes; 51 older adults (22 women and 29 men) without LMM were recruited for the study, including 13 (5 women and 8 men) with LMM who visited the National Center for Geriatric and Gerontology for volunteering purposes; 51 older adults (22 women and 29 men) without LMM were recruited as the control group.

Participants with severe radicular pain and/or motor weakness in the lower extremities that affected their standing posture, spinal infection, spinal tumors, vertebral fractures, and a history of previous back surgery were excluded from this study. All investigations were conducted according to the guidelines in the Declaration of Helsinki. The Ethics Committee of the National Center for Geriatrics and Gerontology approved the study (IRB approval number: 586).

2. Measurement of different parameters

The muscle mass was measured using dual-energy X-ray absorptiometry (Lunar DPX, Madison, WI, USA). The lower skeletal muscle mass (LSMM) was calculated as the sum of the fat-free soft tissue or fat tissue mass in the legs. The lower limb skeletal muscle mass index (LSMI) was calculated as LSMM / height\(^2\).

The lumbar lordosis angle and sacral cornua angle were measured using SYNAPSE (Fujifilm Medical Co., Ltd., Tokyo, Japan), an area calculation software program used to measure the lumbar multifidus (LM) and erector spinae muscle cross-sectional area at L4/5 based on magnetic resonance imaging. Data analysis for the trunk muscle was performed using SYNAPSE. The L4/5 LM cross-sectional area ratio was calculated as (LM cross-sectional area) / (LM cross-sectional area + erector spinae muscle cross-sectional area) \times 100\(^\circ\).

The center of pressure (COP) was recorded using a balance board (Wii Balance Board, Nintendo Co., Ltd., Kyoto, Japan)\(^9,10\). A vibratory stimulus was applied alternatively to two muscles by fixing two vibrators from the device onto the participants’ gastrocnemius (GS) and LM muscles. The participants stood barefoot on the balance board with their eyes closed and their feet together. They were instructed to remain relaxed and still on the board quietly with their arms hanging loosely by their sides. Vibratory stimulus was applied to the GS muscle at the maximum bulge and the LM muscle at L4. Only one trial was allowed for each vibration stimulus. Each participant’s COP was measured under six conditions: (the two muscles \times three frequencies of vibratory stimulation) (1) 30 Hz on GS, (2) 30 Hz on LM, (3) 60 Hz on GS, (4) 60 Hz on LM, (5) 240 Hz on GS, and (6) 240 Hz on LM in that order\(^6,11\). The measurement time was 30 s, which was divided into two intervals of 15 s each. Vibratory stimulus was applied to the participants during the last 15 s. The first 15-s interval was labeled as “Pre” and the last 15 s as “During.” The participants rested on a chair for 60 s between each measurement. To obtain additional information regarding proprioceptive dominance, the relative proprioceptive weighting ratio (RPW) was calculated using the following equation: RPW = (Abs GS) / (Abs GS + Abs LM) \times 100 \([\%]\), where Abs GS and Abs LM are the absolute values of the mean COP displacement during GS and LM stimulations, respectively\(^6,11\). The mean COP was calculated as follows: \(\Delta Y = Y (\text{During}) - Y (\text{Pre})\). To correct the COP in the During data based on the COP in the Pre data, COP in the During data was subtracted from the mean value of COP in the Pre data.

3. Statistical analysis

The data were analyzed using the Statistical Package for Social Sciences version 19.0 for Windows (SPSS Inc., Chicago, IL, USA). \(P < 0.05\) was considered statistically significant. The data were expressed as mean values with standard deviations. Data from the LMM and NLMM groups were compared using the independent t-test and the chi-squared test.

Results

Table 1 shows the characteristics of the study participants and a comparison between the groups. The subjects in the LMM group showed lower weight (\(p < 0.001\)) and significantly lower body mass index (\(p < 0.001\)) than those in the NLMM group (Table 1). The age, height, COP at 30, 60, and 240 Hz, lumbar lordosis angle, and sacral cornua angle were not significantly different. There were no significant differences in the RPW 30 Hz and 240 Hz and the L4/5 lumbar multifidus cross-sectional area ratio between the NLMM and the LMM groups (Table 1 and Table 2). Meanwhile, compared to the NLMM group, individuals in the LMM group showed lower RPW 60 Hz (\(p < 0.05\) and LSMI (\(p < 0.01\)) (Table 2).

Discussion

In this study, we found that the LMM group showed a greater decline in the proprioception of the lower leg skeletal muscle spindles compared to the NLMM group. In previous studies, vibratory stimulations targeting only muscle...
to be impaired owing to LMM in the lower leg. Previously, balance has been shown that the function of the muscle spindles in the lower leg was impaired. Therefore, to maintain balance, elderly individuals with LMM utilize the postural control of the hip and rely on the trunk because of weak proprioceptive input of the muscle spindles in the lower leg. These elderly individuals may also have difficulty in maintaining postural control using proprioception of the muscle spindles.

In this study, the LSMI was significantly lower in the LMM group than in the NLMM group. Conversely, there was no significant difference in the cross-sectional area ratio of the L4/5 LM. Thus, in the LMM group, we speculate that the function of the muscle spindles in the lower leg may have declined.

Based on these results, we speculate that elderly individuals with LMM have decreased lower leg muscle mass and consequently, impaired proprioception of the lower leg muscle spindles, which results in the predominance of postural control of the trunk and reduced balance.

### 1. Limitations

This study has several limitations. First, the sample size was small. Second, the walking speed of the participants was not evaluated; hence, accurate diagnosis based on walk speed was small. Second, the walking speed of the participants was not evaluated; hence, accurate diagnosis based on walk speed.
the definition of sarcopenia was not possible.

**Conclusions**

The results of this study suggested that the proprioception of the lower leg skeletal muscle spindles decline with respect to the gastrocnemius muscles in older adults with LMM. Further assessments using stimuli applied to muscle spindles will be necessary.

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**Conflict of Interest:** There is no conflict of interest to disclose.

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