3. Results

The numbers of subjects in age groups of ≤24, 25–34, 35–44, 45–54, 55–64, 65–74 and ≥75 years was 34, 19, 20, 17, 22, 27 and 24, respectively. No subjects required assistance to prevent falling during upright posture for 60 s in the 4 conditions described above.

First, we assessed the frequency-domain characteristics of aging by comparison of the AUC among each age group in the AP axis (Figs. 1 and 2). For LF-AUC, there were no significant differences in any pairs of multiple-comparisons in any condition. On the other hand, in multiple-comparisons of MF- AUC and HF-AUC among each age group, older age groups showed significantly larger AUCs in comparison with younger age groups in each condition. Comparing the number of pairs in which a significant difference was shown, the condition with foam rubber, especially with eyes open, tended to highlight age-related changes in comparison with the condition without foam rubber. An aging effect in the older age groups was apparent in the AP axis: the value of ≥75 years group was significantly larger than that of 65–74 years group though only in MF-AUC in eyes open/foam rubber condition.

We then assessed the frequency-domain characteristics of aging by comparison of the AUC among each age group in the ML axis (Figs. 3 and 4). For LF-AUC, only in the condition with eyes closed without foam rubber, was the value of the ≥75 years group significantly larger than younger age groups. On the other hand, in multiple-comparisons of MF-AUC and HF-AUC among each age group, older age groups showed larger AUCs in comparison with younger age groups in each condition. Comparing the number of pairs in which a significant difference was shown, the condition with foam rubber, especially with eyes open, tended to generate age-related changes in comparison with conditions without foam rubber. This tendency in the ML axis was similar to that found in the AP axis. In the eyes open/foam rubber condition, the MF-AUC of the ≥75 years group was significantly larger than that of the 65–74

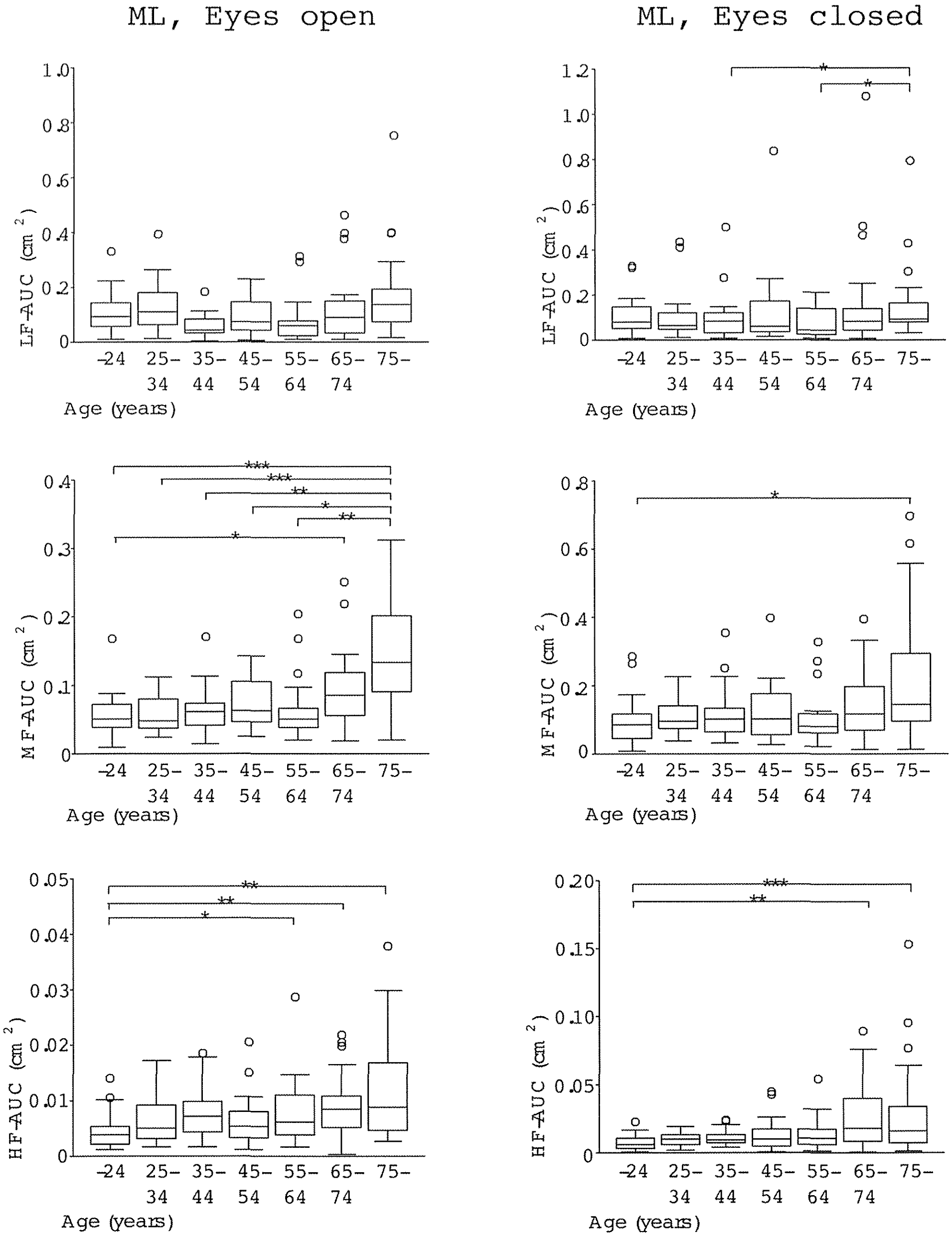

Fig. 3. Box plots of LF-, MF-, and HF-AUC of the ML axis in the condition without foam rubber in each age group. * = Significant difference in nonparametric Steel–Dwass method (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).

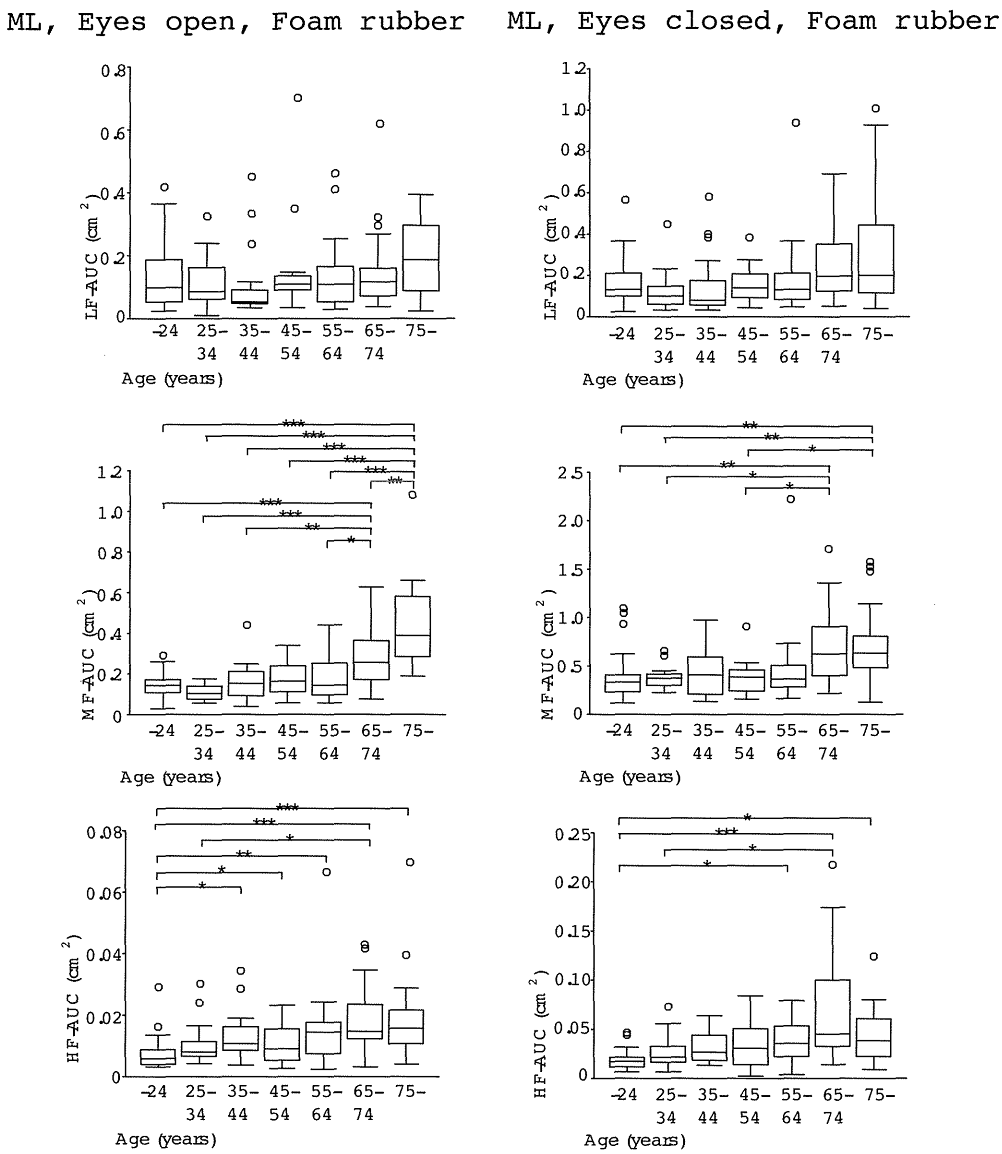

Fig. 4. Box plots of LF-, MF-, and HF-AUC of the AP axis in the condition with foam rubber in each age group. * = Significant difference in nonparametric Steel–Dwass method (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).

years group and the MF-AUC of the 65–74 years group was significantly higher than that of the 55–64 years group, On the other hand, there were no significant differences of MF-AUC among age groups under 54 years.

MF-AUC of the ML axis in the eyes open/foam rubber condition was specifically influenced by an aging effect on static postural control in late-middle-aged (ages 55–64) and older subjects. In the eyes open/foam rubber condition, although HF-AUC did not change over 35 years old, HF-AUC of each age group over 35 years old was significantly larger than that of the <24 years age group, suggesting that HF-AUC in the ML axis in this condition was specifically influenced by changes in static postural control in the early-middle-age period (ages 35–44).

4. Discussion

For LF-AUC in both the AP and ML axes, there were no significant differences in pairs in each condition between the younger and older age groups. On the other hand, for MF-AUC and HF-AUC in both axes, older age groups showed significantly larger AUCs in comparison with younger age groups in each condition. The analyses demonstrated that disturbance of somatosensory inputs by using foam rubber tended to generate a difference in MF-AUC and HF-AUC between younger and older age group. An aging effect on postural stability could mainly be seen in the frequency component above 0.1 Hz as a result of disturbance to the somatosensory inputs.

In both the AP and ML axis, the value of the ≥75 years group was significantly larger than that of the 65–74 years group in MF-AUC only in the eyes open/foam rubber condition. Additionally, only in the ML axis in the eyes open/foam rubber condition, was the MF-AUC of the 65–74 years group significantly higher than that of the 55–64 years group, while there were no significant differences of MF-AUC among age groups under 54 years. Therefore, it appears that MF-AUC of the ML axis in the eyes open/foam rubber condition was specifically influenced by an aging effect on static postural control in late-middle-age and older subjects. On the other hand, in the eyes closed/foam rubber condition, no obvious differences in the AUC were found among the 55–64 years group, 65–74 years group and ≥75 years group. The eyes closed/foam rubber condition causes not only a degradation of somatosensory input but also an absence of visual input and makes the value of MF-AUCs larger [5]. This condition may be too physically demanding to generate a difference in postural instability among late-middle-age and older groups.

For the ML axis in the eyes open/foam rubber condition, HF-AUC increased up to 35 years old but remained unchanged over 35 years old, suggesting that HF-AUC of the ML axis in the eyes open/foam rubber condition was specifically influenced by an aging effect on static postural control in the early-middle-age period. So far, little is known about the change in postural control in the early-middle-age period. It has been previously reported that the differences in balance control between subjects belonging to different age categories were already apparent among young and middle-aged subjects, although these differences were small and only detected by the more accurate force platform measurements [3]. The age-specific HF-AUC change in the eyes open/foam rubber condition in the early-middle-age period might be related to an early change in plantar cutaneous sensation.

In the ML axis, both MF-AUC, and HF-AUC were specifically influenced by an aging effect in the eyes open/foam rubber condition: MF-AUC in late-middle-aged and older subjects, HF-AUC in early-middle-aged subjects. The characteristic difference between the AP and ML axes in the frequency of COP sway during aging has been reported previously [15]. The study showed that elderly subjects exhibited a shift in the distribution of spectral power from higher (>0.5 Hz) to lower frequencies (<0.5 Hz) only in the ML axis in the eyes open condition. It is not known what causes the characteristic age-related differences frequency between the axes. A possible reason could be different movement strategies between the two axes in order to maintain stability. For the ML axis, it has been proposed that the hip strategy is commonly used in response to perturbations designed to disrupt balance [12,17]. On the other hand, for the AP axis, the main movement strategy in response to perturbations is the ankle strategy, although the hip strategy is also used [10]. Therefore, the selection of the control strategy may reflect the age-related difference between the two axes.

5. Conclusions

We assessed age-related frequency-domain characteristics of the sway of COP in foam posturography, The condition with foam rubber, especially with eyes open, tended to highlight age-related changes. In the ML axis in the eyes open/foam rubber condition, MF-AUC is specifically affected by age in late-middle-aged and older subjects, while HF-AUC is specifically affected by age in early-middle-aged subjects. This study clarified age-related changes in the frequency-domain characteristics of postural control on postural control in two-legged stance tasks. The result may be helpful for development of research related to fall prevention and medical interventions for the postural instability in the elderly.

Conflict of interest

The authors declare that they have no competing interests.

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