STRATEGIES FOR BALANCE MAINTENANCE DURING SIT-TO-STAND MOVEMENT IN ELDERLY PEOPLE

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INTRODUCTION

Sit-to-stand (STS) movement is one of the daily activities that the elderly feel anxiety of falling (Tinetti et al., 1990). It requires a precise shifting of the center of mass (COM) to maintain balance. In addition, it demands significant muscular power at the knee, which depends on the COM position and acceleration. The COM acceleration also determines dynamic limits of balance control. Therefore, COM position and its acceleration are important factors governing STS movement. The objectives of this study were to investigate balance control during STS and to identify the differences in strategies for STS in terms of COM position and acceleration between elderly people with and without difficulty in STS in order to reveal underlying causes of the difficulty. Applying a concept of dynamic stability area (DSA), the relationship between the COM and the DSA was investigated.

METHODS AND PROCEDURES

Ten subjects participated in this study: 6 young males (Young (NORM), mean age = 22.7±1.2 years) and 4 elderly people (with 2 having difficulty in STS, Elderly (DIFF), and 2 healthy elderly, Elderly (NORM); mean age = 80.5±3.5 and 81.0±1.4 years, respectively). All subjects were asked to stand up from a 40 cm high chair as they normally do. Each subject performed 5 trials. Motion data was captured with a motion analysis system (Motion Analysis Corp.). Markers were placed on the subject's bony landmarks according to Helen Hayes marker set (Kabada et al, 1990), as well as the estimated position of the hip joint and the fifth metatarsal bone. Two forceplates (AMTI) were used to collect floor reaction forces (FRF) for the calculation of center of pressure (COP). Net joint moments acting at the ankle, knee, and hip were estimated with inverse dynamics using a rigid link model defined by markers. The DSA was derived based on an inverted pendulum model (Fig.1; Mourey et al, 2000):

$$X_h - A\ddot{X} \leq X \leq X_t - A\ddot{X} \qquad (1)$$

where X indicates the COM position in the antero-posterior (A-P) direction, $\ddot{X}$ indicates its acceleration, and $A = l/g$. X_h and X_t indicate the heel and toe position, respectively. The relationship when $\ddot{X}$ is zero defines the static stability area (SSA), the area within the base of support.

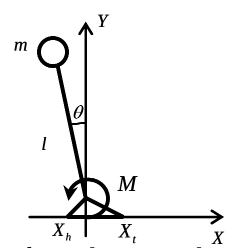

Figure 1. Model of simple inverted pendulum

RESULTS AND DISCUSSION

The relationship between the COM position and its acceleration (both were normalized to the foot length) at the instant of seat-off is shown in Fig.2. The area between 0 and 100 indicates the SSA, and the area within two solid lines indicates the DSA. All but three trials preformed by Young (NORM) and Elderly (NORM) were located in the DSA region, whereas all trials preformed by Elderly (DIFF) were located within the SSA. Elderly (DIFF) were found to stand up with a greater trunk forward bending angle than Elderly (NORM) and Young (NORM) (51.2±5.3, 24.0±5.2, and 21.1±5.2 deg from vertical line, respectively) and with a smaller COM acceleration than Elderly (NORM) and Young (NORM), which allow them to control the COM motion within the SSA.

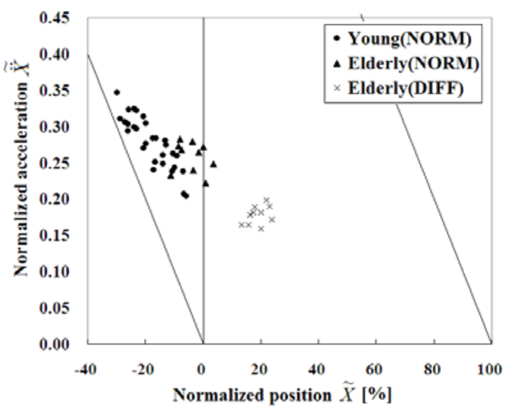

Figure 2. Relationship between normalized COM position and acceleration at the instant of seat-off.

Elderly (DIFF) were further found to demonstrate greater hip and ankle joint moments and a smaller knee joint moment at seat-off when compared to those of the healthy groups (Fig.3). Furthermore, the A-P COP displacement of Elderly (DIFF) was higher than those of Elderly (NORM) and Young (NORM) (Fig.4).

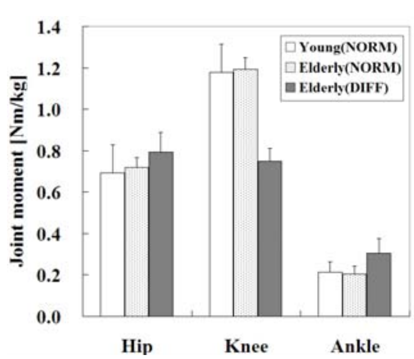

Figure 3. Joint moments at the instant of seat-off. The values were averaged for both legs and normalized by their body weight.

It is reasonable to expect that Elderly (DIFF) bent their trunk forward at seat-off to shift the COM to a more anterior position and achieve a more statically balanced posture, which results in a shorter moment arm for the knee joint.

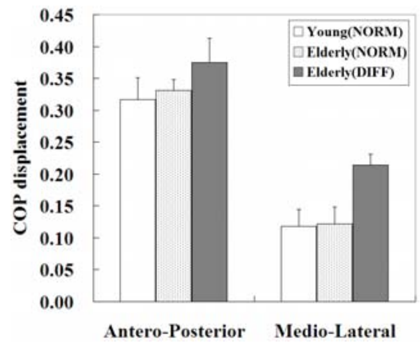

Figure 4. COP displacement in the antero-posterior and medio-lateral directions.

SUMMARY

Findings from this study suggest that elderly people having difficulty in STS have to carefully perform the task with a controlled COM position and acceleration that ensures a static stability (located in the SSA). A strategy of bending the trunk further forward was identified, which allows the Elderly (DIFF) to maintain the COM motion within the SSA and decreases the muscle demand at the knee.

REFERENCES

Tinetti, M.E., et al. (1990), *J.Gerontol. Psychol. Sci.*, 45-6, 239-243.

Kadaba, M. P., et al. (1990), *J. Orthop. Res.*, 8, 383-392.

Mourey, F., et al. (2000), *J.Gerontol. Bio. Sci.*, 55A-9, B425-B431.

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