Higher Nervous Control System in Bipedally Walking Japanese Monkey, *Macaca fuscata*

F. Mori[1] and S. Mori[2]

National Institute for Physiological Sciences, Dept. Biological Control System, Okazaki 444-8585, [1]fmori@nips.ac.jp, [2]mrsgm@nips.ac.jp

1. Introduction

For the execution of stable bipedal (BP) locomotion, we must incessantly adjust our posture in the face of various perturbations. Such adjustments can be accomplished by recruiting both anticipatory and reactive control mechanisms. For the better understanding of the critical components in Bp locomotion, it is indispensable to have an animal model that can provide multi-system-level studies. We have recently developed a non-human primate model that successfully elaborates Bp locomotion on a moving treadmill belt [1, 2]. This study focused on the evaluation how Bp-trained monkeys can control their locomotor pattern to the changes in treadmill grade, and to the postural and gait perturbation.

2. Materials and Methods

Two adult monkeys that already acquired the skill of stable Bp locomotion were the subjects of this study. Behavioral characteristics of monkey's locomotion were routinely analyzed by use of high-speed video camera. Postural and kinematic features of the walking monkeys were analyzed by drawing stick pictures. Then the monkeys were required to walk on 1) slanted and 2) obstacle-attached treadmill belt. To study uphill vs. downhill locomotion, the treadmill grade was set to 7, 15 degrees both up and down relative to the horizontal (0 degree) surface. To study obstacle clearance vs. stumbling, a small adjustable-height rectangular block was placed on the left side of the treadmill belt.

3. Results

3.1. Slanted treadmill locomotion

Between the body axis angle and the treadmill grade, and between the stride length and treadmill grade, there were near linear relationship and these relationships were observed in all three tested treadmill speeds. These results demonstrate that bipedally walking monkeys have utilized reactively optimal kinematic parameters for the coordination of multiple motor segments during slanted walking (reactive control).

3.2. Perturbed locomotion

The monkeys either cleared the obstacle or stumbled over it. After the acquisition of "knee-hip flexion" strategy to clear the obstacle, they have prepared for the obstacle clearance with higher-than-usual foot trajectory, even when they do not encounter the obstacle (anticipatory control). When they stumbled over the obstacle with less attention, they took a defensive posture to avoid falling (reactive control). After the restoration of both head and body position, they regained the stable Bp locomotion.

4. Discussions

These findings suggest that the central nervous system (CNS) of the Bp walking monkey received and transformed salient visual, vestibular, proprioceptive, and exteroceptive sensory information into output (command) motor signals appropriate for the integration of multiple body segments which is essential for successful accommodation to the external demands. Such an accommodation mechanism would allow the monkey and human subjects to adjust incessantly their ongoing locomotor patterns and accompanying posture, and thus to respond to the slanted walking path, and even to the unexpected postural and gait perturbations.

Reference

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[2] Nakajima, K., et al., 2001, Integration of upright posture and bipedal locomotion in non-human primates. In: *Sensorimotor Control* (eds. R. Dengler and A. R. Kossev), IOS Press, Amsterdam, pp. 95-10