A STUDY ON POSTURAL RESPONSE TO LATERAL PERTURBATION

Takuya Goto[1 2], Akiko Imura[1], Takahiro Higuchi[1]

Department of Health Promotion Science
Tokyo Metropolitan University, Tokyo, Japan[1]
Department of Rehabilitation, Yagi Hospital, Kanagawa, Japan[2]

The purpose of this study was to investigate how to postural control in reactive recovery response to lateral perturbations. Twenty-one healthy young adluts participated in this experiment. Each participant was tested for twenty-four trials in which four different perturbation magnitudes and two perturbation directions (left and right) were randamly arranged. In the trials, the participants stood in a standard neutral position. In the group with large angular momentum of the whole body in the frontal plane, the peak horizontal ground reaction force towards the fall side and the peak ankle supinator torque of the fall side limb were significantly larger than those in the small angular momentum group ($p<0.01$). In order to reduce the angular momentum of the whole body, it was suggested that the strength of the ankle joint torque on the loaded side is important.

KEYWORDS: lateral perturbation, floor translation, angular momentum .

INTRODUCTION: Falling in the sideways direction is likely to cause a heavy impact on the hip joint such as a hip fracture (Yang, Mackey, Ambrose, Feldman, & Robinovitch, 2016). More recent researches have focused on stepping after initial reaction for balance recovery to the lateral perturbation (Mille, Johnson, Martinez & Rogers, 2005; Fujimoto, Bair, & Rogers, 2015; Bair, Prettyman, Beamer, &Rogers, 2016). Furthermore, most of the studies have caused lateral perturbations by waist-pull. This means that an external force by waist-pull will occur near the body center of mass. Thus, they could not have evaluated the action of the kinetic chain in the lower limbs accurately. Kinetics of the initial reaction for balance recovery has not been investigated sufficiently. It is important to investigate the postural control against the perturbations from a view of kinetics to consider preventive rehabilitation of the falling.
The aim of this study was to investigate how postural controls were perfomed in response to the lateral perturbations by floor translation. The hypotheses were that 1) Both peak ground reaction force and the corresponding timing of the peak would differ depending on the peak angular momentum of the whole body in the frontal plane. 2) The hip abductor/adductor torque would differ depending on the angular momentum of the whole body.

METHODS: Twenty-one young adult individuals (11 Males and 10 Females; age: 22±3y; height: 1.66±0.07m; body mass: 58.6±8.6kg) participated in the present study with no medical history and neuromuscular diseases. For all participants, the right hand and leg were dominant. Written informed consent was obtained from each participant prior to the experiment. The protocol was approved by the ethics committee at the Tokyo Metropolitan University in accordance with the Declaration of Helsinki.
Participants stood on one foot on a force platform (Kistler) and the other foot on another force platform, wearing a lightweight harness to prevent falling. The force platforms were fixed on a large flat platform (1.3m×2m) that permitted unobstructed stepping. The platform was free to slide along two parallel shafts in both right and left direction without any rotation. A 12-infrared camera three-dimensional motion capture system (Qualisys) and force platforms simultaneously captured the reaction to the lateral perturbation with sampling rates at 200 Hz and 1000 Hz, respectively.
Each participant was asked to react to the lateral pertubations, which were changed randomly in eight trials per block with three different magnitudes (amplitude:10cm; velocity:0.48-0.85m/s; acceleration:5.49-17.0m/s^2) and two directions (left and right). All the participants joined three blocks with appropriate rest. In the trials, participants stood in a

standard position with the angle between medial foot margins of 14° and heel–center spacing 11% of body height (Maki, McIlroy & Perry, 1999).
The analyzed trials were the largest perturbation towards the left in the present study. The analyzed period was 1.5 seconds from the start of the perturbation. The peak horizontal ground reaction force towards the fall side and corresponding timing of the peak appeared were determined.
The angular momentum of the whole body and joint torques were determined in the frontal plane using a standard inverse dynamics method. The body parameters were determined after Ae et al. (1992). The marker coordinates and force platform data were filtered using a Butterworth low-pass filter with a cut-off frequency of 12Hz. The ground reaction forces during the trials were determined by subtracting the force data when the flat platform moved without loading anything on the force platform in two directions at every perturbation magnitude. The angular momentum around the CoM of the upper body and each limb was quantified in the frontal plane as follows:

$$H = \Sigma\,[(r_i - r_{CoM}) \times m_i v_i + I_i \omega_i] \qquad (1)$$

where ri is the CoM position of a segment i; rCoM is the CoM position of each body part; mi is a mass of the segment i; vi is the CoM velocity of a segment i, relative to that of each body part; Ii is the moment of inertia matrix of the segment i; and ωi is the angular velocity of the segment i. In order to grasp the characteristics of the postural control, we picked people whose peak angular momentum of the whole body were the largest three for large angular momentum (LAGM) group and people whose peak angular momentum of the whole body were the smallest three for small angular momentum (SAGM) group. Peak joint torques of the lower limbs in the frontal plane (Hip adductor/abductor torque; ankle pronator/supinator torque) and corrsponding timing of the peak appeared were determined during each phase. The phase was bimodal, and peak torques and corrsponding timing of the peak appeared were calculated for each phase in each subject. An unpaired T test was used for comparison of horizontal ground reaction force and joint torques of the lower limbs in the frontal plane between groups using R (version 2.8.1). A p value less than 0.05 was considered statistically significant.

RESULTS: There was a significant difference in the peak horizontal ground reaction force towards the fall side (p<0.01), but no significant difference was observed in the corresponding timing to the peak (Figure1). There was a significant difference in the joint torques of the lower extremity on the ankle pronator torque of fall side (right-side)(p<0.01), but no significant difference in other joint torque and corresponding timing of the peak appeared (Figure2)

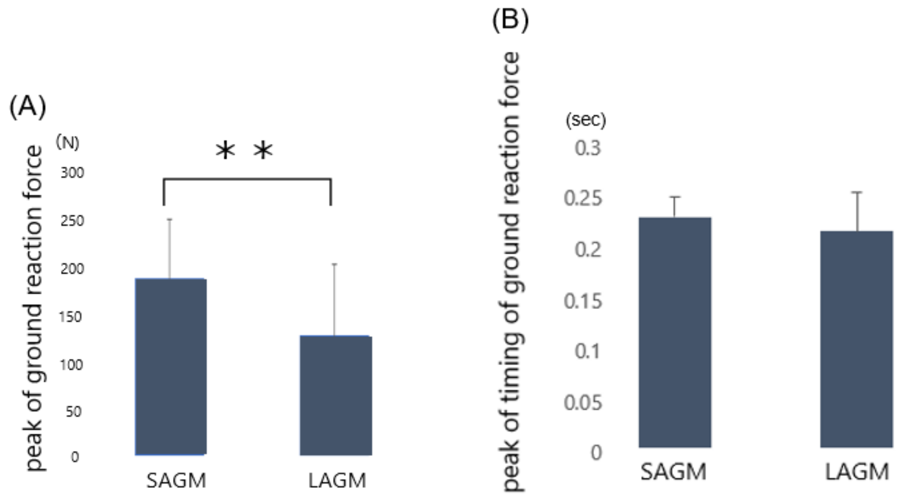

Figure 1: Peak horizontal ground reaction force towards the fall side and the corresponding timing of the peak appeared (right-side). (A: peak force; B: timing)

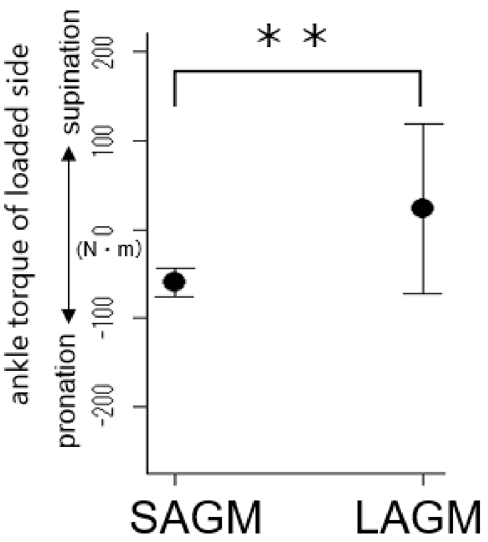

Figure 2: Ankle pronator torque of fall side (right-side).

DISCUSSION: The aim of this study was to investigate how postural controls were perfomed in response to the lateral perturbations by floor translation.
The hypotheses were that 1) Both peak ground reaction force and the corresponding timing of the peak appeared would differ depending on the peak angular momentum of the whole body in the frontal plane. 2) The hip abductor/adductor torque would differ depending on the angular momentum of the whole body. The first hypothesis was supported in view of the peak force. The second hypothesis was not supported. We suggested the element for determining the magnitude of whole of angular momentum was intensity of the peak rather than the timing of peak pushes the foot on the floor.
This suggests that the horizontal ground reaction force vector pushing back the floor act on the body center of mass.
The fact that the ankle joint torque peak value of the SAGM group was significantly large, suggests that reflexive efferent torque was sufficient in initial reactive recovery response to lateral perturbation. Generally, many researchers have proposed that in contrast to anteroposterior postural control, balance control against the lateral perturbations occurs primarily at the hip and trunk, rather than at the ankle joint (Rogers & Mille, 2003; Shumway-Cook & Woollacott, 2012). However, in this study, there was no significant difference in the hip joint. Our results indicated that in the initial response to the lateral perturbations, pronator torque of fall side rather than the hip abductor/adductor torque affected the magnitude of the angular momentum. This is considered to have an outside influence since the phase to be analyzed is limited to the initial reactive response. Therefore, if it is a slightly strong perturbation stimulus such as the step occurs or a perturbation on a narrow supporting base surface, there is a possibility that a relationship may have occurred between the angular momentum of the whole body and the muscle torque of the hip joint.
These two differences suggested that the angular momentum of the whole body of the SAGM group became smaller than that of the LAGM group.
In considering the prevention of falls against the lateral perturbation, the strength of the ankle joint torque and the horizontal ground reaction force towards the fall side would influence on the postural recovery rather than the hip joint which has been conventionally mentioned. Therefore, improvement of the control ability in the frontal plane using the ankle pronator torque on the fall side would be needed in the rehabilitation to prevent femoral fractures (such as preventing re-fall) when the lateral perturbation occurred in the lower limbs.

CONCLUSION: Under the conditions that lateral perturbation to the extent that no stepping occurs, it was suggested that the strength of the ankle joint torque on the load side was important to reduce the angular momentum of the whole body.

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