CHARACTERISTICS OF INVERTED PENDULUM MOVEMENT IN ELDERLY WALKING

Takashi Mitsui¹ and Koji Zushi²,³

¹ Graduate School of Physical Education, National Institute of Fitness and Sports in Kanoaya, Japan
e-mail: k025004@sky.nifs-k.ac.jp
² Faculty of Physical Education, National Institute of Fitness and Sports in Kanoaya, Japan
³ School of Human Movement and Exercise Science, The University of Western Australia, Australia

INTRODUCTION

It is reported that the elderly have difficulty in increasing their stride length (SL) or walking speed, even though functionally their abilities were improved after certain training sessions. From a mechanical point of view, walking is often modeled as an inverted pendulum system with a leg and when increasing SL it is necessary for the leg to produce greater force to move center of gravity forward. We hypothesized that this simple model would be appropriate to describe the characteristics of elderly gait and clarify ways to increase their SL.

The purpose of the present study was to investigate factors to increase SL in the elderly with special reference to inverted pendulum movement to design an effective training method for improving their gait ability.

METHODS

9 elderly (84.1±6.1, 73-93yrs) walked at three different SL (free, wide, and supra wide) on the floor. Kinematics and ground reaction forces were recorded using by video camera (60Hz) and force platforms (1.25kHz). The Subjects were modeled as an inverted pendulum system including a compliant leg, connecting center of gravity (CG) and center of pressure (CoP). SL was divide into two phases, the former and the latter phase, and calculated by the following equation.

\[ \text{SL} = L \sin \theta_{\text{pendulum}} \]

where \( L \) is the limb length (the distance between CG and CoP), \( \theta_{\text{pendulum}} \) is the range of pendulum angle (the angle between \( L \) and the vertical) in each phase. There was significant correlation between SL, which was calculated by the traditional method (the distance between toe-heel) and the present method (r=0.963, p<0.001).

RESULTS AND DISCUSSION

The decline of speed in the elderly during free walking was affected by SL (r=0.810, p<0.01) but not stride frequency (r=0.073, n.s.). Also, this decline of both speed and SL were significantly affected by age (speed, r=0.892, p<0.01; SL, r=0.822, p<0.01). Similar results were found in the previous studies.

Figure 1. shows the relationship between normalized SL and range of pendulum angle (r=0.889, p<0.001).

Figure 2. shows the relationship between the range of pendulum angle and amount of change of limb length in a step during walking, in the former phase and longer in the latter phase with increasing \( \theta_{\text{pendulum}} \) (r=0.889, p<0.001).

Figure 3. shows the relationships between \( \theta_{\text{pendulum}} \) and negative (a) and positive impulse (b). Both negative and positive impulse in each phase were associated with \( \theta_{\text{pendulum}} \) and regression analysis revealed positive relationships (former phase, r=0.819, p<0.001; latter phase, r=0.852, p<0.001).

With increasing SL, subjects generated greater force in both the former and latter phase with a large change in the limb length. Limb shortening with large negative forces in the former phase may work to reduce moment inertia for the CG rotation and maintain the body balance. In contrast, limb lengthening with large positive forces in the latter phase would play an important role in rotation and acceleration of the CG further forward.

SUMMARY

To increase SL greater change in the limb length, spring-like behavior of leg movement could be important factor for the elderly to produce greater force, which is necessary to rotate CG largely about contact foot as an inverted pendulum.

REFERENCES