Effects of Approaching Direction to the Obstacle Avoidance Movements

1 Yoshiyuki Kobayashi, 2Takeyuki Harashima, 3Hiroshi Izumikawa and 4Hiroshi Fujimoto
1National Institute of Advanced Industrial Science and Technology (AIST), email:kobayashi-yoshiyuki@aist.go.jp,
2Waseda University, Graduate School of Human Sciences

SUMMARY
Present study focused on the effect of approaching directions to obstacle-avoidance movement. Ten young and 10 elderly participants were asked to step over the obstacle with various heights (25, 50, and 150mm) while they approaching from 7 different directions (-60 to +60 degrees). Participants repeated each obstacle condition for 5 times, total of 63 trials. Kinematics while the participants step over the obstacles was recorded using 3-D motion capturing system, and was compared the following parameters among the conditions: toe clearances, step length, and step width. The results revealed that the approaching direction to the obstacles do not critically affect to the obstacle-avoidance movement in terms of tripping risks, but it (especially for +60 condition) critically affect to the movements in terms of loss-of-balance. Moreover, present study confirmed that people actually stepped over the obstacles with Risky movement even if there are no experimental constraints.

INTRODUCTION
The objective of this research was to clarify the feature of gait patterns in healthy young and older adults as they stepped over the obstacles with different heights while approaching from various directions.
Although the kinematics and kinetics of human motion while stepping over obstacles have been well investigated over the last two decades, still little is known about the effects of approaching directions to the obstacles-avoidance movement. Since most of the environmental hazards that listed as a cause of falling (e.g. carpet edges, door thresholds or electrical/telephone cable) are accessible from various directions, we believe that examining the effect of approaching direction to the obstacle-avoidance movement is a critical research area.

METHODS
Ten healthy young adults (mean age: 21.9 SD: 1.2) and 10 older adults (mean age: 70.30 SD: 3.50) were recruited to participate in this study. All protocols were reviewed and approved by the Local Ethical Committee.
Experiments were performed in a large room with a straight 10-m travel path available for the participants to walk on. A three dimensional motion-capture system (VICON 612, OXFORD METRICS) with 8 cameras and two force plates (AMTI) was used to record the kinematic and kinetic data while participants step over the obstacles. Kinematic data were obtained from 13 IR-reflective markers recording at 100 Hz that were placed on the participants’ lower limb and Sacral.

RESULTS AND DISCUSSION
TOE CLEARANCE (TC)
Group means for the TC are presented in Figure 2. The result of the three-way ANOVA revealed significant interaction among the conditions (directions*heights*age) [F(12,204) = 2.505, P<.01]. The results of post-hoc analysis showed that 1) in most cases, approaching directions did not affect to the TC of young and elderly participants, and 2) young adults maintained larger TC when they stepping over higher obstacles (i.e. 150mm), which is consistent with several previous studies.

STEP LENGTH (SL)
Group means for the SL are presented in Figure 3. The result of the three-way ANOVA revealed significant interaction
between the directions*age \([F_{(6,108)} = 3.855, P<.01]\), and heights*age \([F_{(2,36)} = 5.149, P<.05]\). The results of post-hoc analysis showed that 1) young participants tend to maintain longer SL during +20~+60 conditions, but 2) such tendency was not seen in elderly participants. Moreover, 3) young participants maintained longer SL when they encountered higher obstacles regardless of the approaching direction.

**STEP WIDTH (SW)**

Group means for the SW are presented in Figure 4. The graph clearly shows the effect of approaching directions, and the result of three-way ANOVA indicates significant age effect \([F_{(1,18)} = 5.004, P<.05]\) and interaction between the directions*heights \([F_{(12,216)} = 4.098, P<.01]\). The results of post-hoc analysis revealed that approaching direction critically affect to the SW regardless of age. Especially during +40~+60 conditions, people maintained less than half SW than ordinary condition (0 degree condition). It is well known that wider steps have advantage in terms of lateral stability. Thus, obstacle-avoidance movement during +20~+60 conditions can be interpret as much RISKY movement than the movement during ordinary condition, in terms of loss-of-balance. This result is no wonder because during +20~+60 conditions, obstacle has sat on the walk way as it obstruct the natural foot placement of leading limb. In such case, participants have to place their leading limb more medial than usual to not to step on the obstacles, unless they alter the leading limb (If participants alter the leading limb, then 20~+60 conditions become -20~+60 conditions. However participants were asked to fix their leading limb during the experiment, in order to control the approaching direction).

**ACTUAL OBSTACLE-AVOIDANCE MOVEMENT**

Consequently, the results of present study may not represent the natural movements of people during daily walking. We therefore conduct further pilot experiment to see how people step over the obstacles when there are no constraint about the leading limb. Ten young and six elderly participants were asked to walk along the travel path, and stepped over the obstacles with similar conditions to the main experiment (i.e. 7 directions * 3 heights).

The results were interesting. First, participants of both age groups stepped over the obstacles with Risky movement for 20~30 % of the trials with 40 or 60 degree condition (positive and negative sign is meaningless in this pilot experiments because participants were free to choose the leading limb). And second, three elderly participants who report recent fall (within a year) tend NOT to step over the obstacles with the RISKY movement. These results indicate that the Risky movement that observed in present study can occur in daily walking. Moreover, we interpret the second result as elderly participants who experienced recent fall walk with extreme caution to avoid next falling.

**CONCLUSIONS**

Present study investigates the effect of approaching directions to obstacle-avoidance movement. The result revealed that approaching directions critically affect to SW in terms of loss-of-balance, and further pilot study confirmed that people tend to step over the obstacles with Risky movement even if they can walk freely. Thus, it is reasonable to think that people actually stepping over encountered obstacles with Risky movement as we observed in present study in daily living.

**ACKNOWLEDGEMENTS**

This study was supported by JSPS Grand-in-Aid for JSPS Fellows (21-10476). Authors would like to thank to the late Prof. Abtab Patla at University of Waterloo for basic idea of the study.

![Figure 2: Toe Clearance among the conditions](image)

![Figure 3: Step Length among the conditions](image)

![Figure 4: Step Width among the conditions](image)