Experimental Verfication of Fall Simulation and Wearable Protect Airbag

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Abstract: Falling of the elderly becomes an important issue in the aging society. Falls could cause fractures which is significant cause of morbidity and mortality. As a result, active protecting devices are being developed to protect fallers' body from severe injuries. In this study, as boundary condition and injury parameter are figured out by experiments and simulation of falls situation, the wearable airbag for protecting from falls is designed and make prototype of airbag. After that, compare contact force between fall simulation and experiments with prototype airbag. It will be possible to establish the reliability of the development of the fall prevention system for the elderly and to be the basis for the future development.

1 INTRODUCTION

Most people experiment fall accident by losing a balance. Especially, more than 30% of the elderly over the age of 65 years have experiences at least one fall per year, which significantly deteriorates quality of life. Based on movements, the elderly falls during the level walking (43 %), going in-and-out of a bathroom (30 %), during sitting down and standing up from a seat (13 %), and in ascending and descending stairs (15 %), which are the activities of daily living (ADL) (W. L. Watson et al., 2011). Particularly, it was found that a slip was a main cause of falling injury. For the elderly, it was reported that more than 66 % of the slip fallers have the hip injuries in pelvis (Ambrose et al., 2013). However, it is still unknown why the slip fallers in the old age have the high injury value at the pelvic region. Many of these falls may be avoided if fall risk assessment and prevention tools where available as an integral part of ADL. However, the fall risk assessment is still not completed at this moment. Currently, active protecting devices for fallers are developing to protect fallers' body from severe injuries as an alternative or for a practical purpose. Developed equipment is divided into passive and active type to protect the body from falling. Research on active equipment is divided into research on fall detection algorithms and research on wearable airbags. In the case of wearable airbags, there are studies to confirm the performance of the airbag using a dummy. However, most studies have designed the airbag only as a shock absorber between the ground and the human body without going through ergonomic design. In this study, the wearable protect airbag is designed and is confirmed through simulation of fall injury situation, and also, compare with the fall experiments by using an accelerometer and a gyro-sensor for an active protecting device from the falling injuries.

2 MATERIALS AND METHODS

2.1 Design of Wearable Protect Airbag and Simulation of Falls

2.1.1 Design of the Wearable Protect Airbag

For falls simulations, human models, environments and algorithms must be applied to simulations. Pedestrian facet model (mathematical dynamic model) provided by the MADYMO program (Release 7.6, TASS international, Netherlands). Wearable protective equipment has high protection performance when it is made of hard material, but users prefer the soft material because they don't want to wear it (Honkanen et al., 2006). Also, since there is a difference in the protection performance according to the wearing method of the wearer or the

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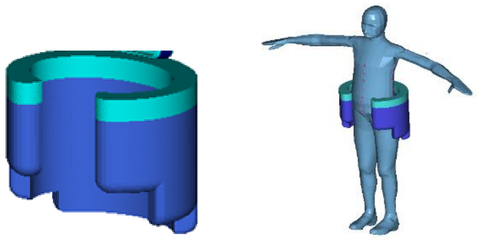
fall method, it is possible to fix the body to the maximum to overcome it (Forsen et al., 2004). The shape of the wearable airbag is designed to cover body and to protect pelvic by considering the average body size of the elderly over 65 years old.



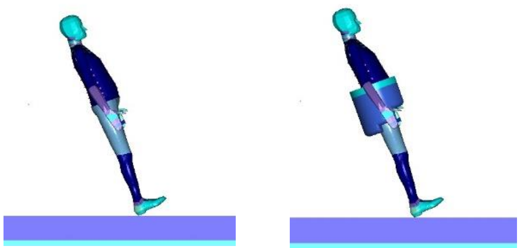
(a) (b)

Figure 1: (a) Designed wearable protect airbag and (b) Human model with wearing airbag.

2.1.2 Simulation of Falls Situation and Reduce the Fall Injury by Airbag

The falling simulation of the human model is designed on a condition of concrete properties (Density: $2300\mathrm{kg}/m^3$, Elastic modulus: $17\mathrm{E}+9\ \mathrm{N}/m^2$, Poisson's ratio: 0.15). and the angle of 70° between the lower limb and the ground is set, where the elderly person cannot maintain and regain the balance (Hsiao, 2008) (Figure 2). Thereafter, gravity is applied to allow the human body to fall back on the ground.

To determine how much the human body model was injured by the falls, Impact force and acceleration is measured in simulation. Acceleration is important parameter to calculate injury, such as HIC (Head Injury Criterion), CTI (Combined Thoracic index) and etc. At the beginning of the simulation, the human body model is tilted toward the ground by gravity. As the angle of the joint cannot be maintained due to the characteristics of the human body model, the joint collapses due to the gravity, and the human body model impacts to the ground in the order of the hips, thorax and head.



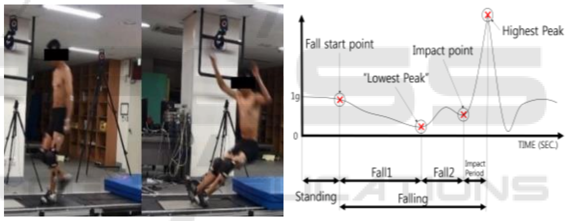
(a) (b)

Figure 2: Initial position of human model in falling simulation (a) without wearable airbag (b) with wearable airbag.

2.2 Fall Experiments

2.2.1 Falling Experiments Toward Backward

21 male subjects participated in the experiment for falling data. The 3D accelerometer (L3G4200D, ± 2000 Deg/sec, 70 mdps/digit), and compass (HMC5883L, ± 8 Gauss, 5 milli-gauss) put on the sacrum, Thoracic and neck of the subjects for the falling experiments. The data from the sensors were wirelessly transmitted by using RF (nRF2401+, 2.4GHz). Fig. 3 (a) shows the experimental setups and an example of the falling experiments, which was using a slider to induce a backward falling. The falling postures were determined based on the resultant pelvic acceleration and angular velocity, and pelvic tilt and obliquity angles. Based on the resultant acceleration as depicted in Fig. 3 (b), a falling event could be classified as the Fall 1; the period from the start of fall to the lowest peak, and the Fall 2 + Impact period; the period from the lowest peak to the highest peak. Using the measured results, the falling posture of the people was analyzed.



(a) (b)

Figure 3: (a) Falling experiments and (b) Definitions of fall.

2.2.2 Falling Experiments by using Dummy Model

60kg-dummy is used in the experiment for falling data. Prototype of wearable pelvic airbag (Figure 4 (a)) is designed by simulation. Wearable protect airbag is manufactured in the form of a belt and can accommodate the airbag. And sensor module (3D accelerometer, gyro-sensor and compass sensor) is used to measure and calculate z-axis acceleration, sum acceleration, angular velocity, tilt angle, obliquity angle, resultant angle. These values is used in double threshold algorithm to determine fall event. If fall event is found, the inside airbag (thermoplastic poly urethane) is unfolded by the gas. Force plate (OR6-7 force platform, ADVANCED MECHANICAL TECHNOLOGY INC, USA) is used to measure contact force between dummy and ground. Dummy is set on 100cm-height from ground.

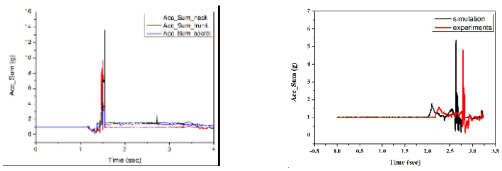
As the angle of the joint cannot be maintained due to the characteristics of the human body model, the joint collapses due to the gravity, and the human body model impacts to the ground in the order of the hips (Figure 4 (b)).

(a) (b)

Figure 4: (a) Prototype of wearable pelvic airbag and (b)Falling experiments by using dummy.

3 RESULTS AND DISCUSSION

After analysing the data collected from movements in fall situation, the summation of acceleration at the neck, thoracic, pelvic could detect almost all movements of the fall. For perfect protection of the falling person's body, the detection should be accomplished within the period from the start of the fall to the lowest peak. And highest peak value can calculate maximum impact force which indicates numerically that the injury occurred to the human body. First, compare the acceleration of each position (neck, thoracic, pelvic) (Figure 1(a)). All of position show similar tendency and lowest peak, but they have different level of highest peak value. The reason for this result is that the sequence of the impact of the human body model with the ground changes in order of hip, head and thoracic.



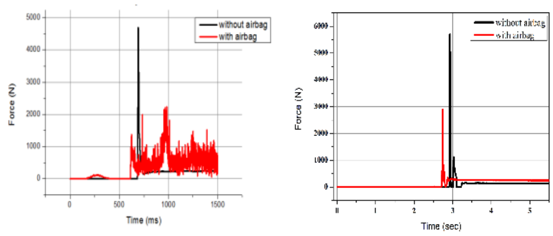
(a) (b)

Figure 5: (a) Sum of acceleration on neck, thoracic and pelvic and (b) Comparison between simulation and experiments of acceleration.

Figure 5(b) show comparison between simulation and experiments. As a result, the simulation is set similarly with experiments. Based on the results of the simulation, the wearable pelvic airbag was developed.

The graph of Figure 6(a) shows the impact force applied to the hips of the human model at the time of the falls in case 1 (before wearing airbag) and case 2 (after wearing airbag) in simulation.

In case 1, maximum impact force is 4694N, and in case 2, maximum impact force is 2240N, respectively. Case 1 (4694N) exceed the reference hip fracture point of the elderly people (3100N) and case 2 (2240N) not exceed (Kennedy, 1987).



(a) (b)

Figure 6: Impact force of before and after wearing pelvic airbag (a) simulation and (b) dummy experiments.

The graph of Figure 6(b) shows the impact force applied to the hips of the dummy at the time of the falls in case 1 (before wearing airbag) and case 2 (after wearing airbag) in simulation.

In case 1, maximum impact force is 5733N, and in case 2, maximum impact force is 2911N, respectively.

4 CONCLUSIONS

In this study, the simulation of the fall and wearable airbag is verified by fall experiments. All condition of simulation is set similarly with real fall situation. It can be simulation method that can be used as a basis of safety research for the elderly.

Based on simulation and experiment results, the effectiveness of the airbag is proved by showing the injury value in the simulation and prototype. This airbag is expected to prevent fractures and reduce cost of treatment. In addition, through this study, it is possible to develop wearable airbags in other parts to prevent injuries caused by falls.

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