

# Design of Belt-type Airbag Cushion System for Preventing Pelvic Injury from Falls

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**Abstract:** Korea became an aged society (more than 14% of elderly population) in 2018 and falls in the elderly can be occurred in all life-cycle. Therefore, various products should be developed for the safety of the elderly. The aim of this study is to design a pelvic airbag cushion system for absorbing falling impact energy. Characteristics of falls in the elderly were identified to develop a product to prevent injury from falls. The characteristics of the elderly and universal design principles were considered in the design of this product. A concept design of this system was developed and then a design modeling was developed using 3D surface modeling program. Finally, a semi-working mockup was developed using 3D printer to check its shape and structure. This product has a wearable belt type of shape and structure. The result of this study can be applied to the development of a pelvic airbag cushion system for absorbing falling impact energy.

**Keywords:** Pelvic airbag cushion system, Falls, Universal design principles, Prototyping

## 1. Background

Korea became an aged society (more than 14% of elderly population) in 2018 and the elderly are often exposed to the danger of accidents. In particular, fall and slip account for 55.3 percent of all accidents in case of the elderly (Korea Consumer Agency 2017). It means that the possibility of falls is very high for the elderly. In fact, because 30 to 50 percent of the elderly over 65 have experiences of fall, five percent of the fallen have trauma such as bone fracture requiring hospitalization and three quarter of people who die as fall are over 65 year old, fall is important health problem of them (Kim, 1998). A fall is often defined as “inadvertently coming to rest on the ground, floor or other lower level, excluding intentional change in position to rest in furniture, wall or other objects” (Stalenhoef et al., 2002). Falls are a common and important health issue for the elderly.

The characteristics of the elderly's falls were analyzed from previous studies. Campbell, Borrie & Spears (1989) said that more than one-thirds of the elderly had falls in the past year. Tabbitts (1996) said that 30 percent of the elderly had experience of fall every year. Cho (1996) said it was 25.3% and Yoo and Lee (2009) said 31.8%. Many researchers also studied for frequency of falls in Korea. Findings show that 30-50 percent among the elderly over 65 has experience of fall, each year. The frequency of falls increases with age and frailty level (Kim and Suh, 2010). The elderly who are living in nursing homes fall more often than those who are living in the community. Approximately 30-50% of people living in long term care institutions fall each year, and 40% of them experienced recurrent falls. About 10 per cent of falls result in serious injury (e.g. fractures). Falls are a leading cause of injury-related hospital admissions and deaths for the elderly. Falls can also lead to the need for residential care (Tinetti, 1987).

From the analysis for the elderly's falls, some characteristics were identified as follows: (1) Elder female have more experiences for falls than male. (2) The elderly who lives alone has higher possibility for falls. (3) Falls can be occurred in any place including the outdoor and the indoor. (4) Old people have falls more frequently in spring and summer. (5) Falls is frequently occurred in everyday life. (6) Falls is most frequently occurred while walking.

Falls are not only related with physical injuries, but must be very importantly considered for the elderly's independent life. Therefore, it is necessary to develop a product to prevent injuries from falls for the elderly's independent life.

## 2. Design Requirement and 3D Modeling

The aim of this study is to design a belt-type airbag cushion system for absorbing falling impact energy. Characteristics of falls in the elderly were identified to develop a product to prevent injury from falls. The characteristics of the elderly and universal design principles were considered in the design of this product. Table 1 is the design requirements of this product considering the elderly's characteristics and universal design principles.

Table 1. Design requirements of belt-type airbag cushion system for preventing pelvic injury from falls

Characteristics of Elderly Falls	Design Requirements	Design Guides
Elder female have more experiences for falls than male),	Aesthetics	Attractive appearance Sporty, compact, and smart shape Sense of sports equipment rather than medical aid
The elderly who lives alone has higher possibility for falls	Wearability	Easy to wear and take off Should not alter the body shape Compatible with clothing Adapted to fit the body
Falls can be occurred in any place including the outdoor and the indoor	Universality	Making the elderly more familiarized with this product Should be used in any circumstances Anybody can use the product regardless of experience, knowledge, human scale, etc.
Old people have falls more frequently in spring and summer	Comfort	Will transport moisture away from the body Will maintain the body temperature Can be used at high temperatures
Falls is frequently occurred in everyday life	Usability	Intuitive and easy to handle Simple maintenance Can be handled despite weak hands or stiff back
Falls is most frequently occurred while walking	Functionality	Protects the hip from falling impacts Will not hinder body movement (walking, sitting ..) Will not hinder body functions

A belt-type airbag cushion system must be designed considering these requirements. That is, the product must have functionality, usability, comfort, safety, aesthetics, and universality. A good impression of the product is crucial and so it is important to consider design requirements and design guides. The belt was designed to round shape to give wearability and aesthetics. The front part of the belt has a buckle to fasten the belt and was designed considering aesthetics. The back part of the belt was widely and thickly designed because it has airbag in the inside. The elderly usually wear this product as a belt round his or her waist. When the elderly fall down, the airbag of the product will inflate. The design modeling is as follows (Figure 1).



Figure 1. 3D modeling of pelvic airbag cushion system

### 3. Rapid Prototyping and Usability Evaluation

A semi-working mockup was developed to check its shape and structure. 3D printers were used to develop mockup for pelvic airbag cushion system. Using 3D modeling results, the mockup was constructed using rapid prototyping. Rapid prototyping is represented by additive manufacturing or 3D printing. 3D CAD model data and CT/MRI scan data can be used in rapid prototyping. In this study, a 29" full-size mockup part was printed out using the rocket Edison plus equipment and the heat-resistant PLA filament (SPLA). Then, the finishing and surface treatment was performed after removing support attached to the circle. Considering the characteristics of the PLA filament material with little flexibility, a parting line was

created at the center of the frame and a neodymium magnet was built in to enable it to be actually worn on the human body. In addition, the mockup was completed by painting in the colors favored by the elderly. Figure 2 is prototyping process using 3D printer,



Figure 2. Prototyping process using 3D printer

Usability evaluation was performed using manufactured mockup. The usability evaluation was conducted primarily on four college students. The subjects were two boys and two girls. The purpose of this usability evaluation was about the ease of wearing the belt-type airbag cushion system. Through usability evaluation, this product has led to the difficulty of automatic length adjustment and double locking, and the weak durability in frequent use. Therefore, the product was redesigned solving these problems. Figure 3 is mockup and usability evaluation process.



Figure 3. Mockup and usability evaluation process

#### 4. Conclusion

In this study, characteristics of elderly falls in Korea were identified from previous studies and a wearable product for protecting pelvis from falls was designed considering the characteristics. For the success of product development, user requirements including ergonomic and emotional characteristics as well as its functional characteristics must be considered. The pelvic airbag cushion system was designed considering the elderly's characteristics for falls and ergonomic aspects. Some prototypes of the product were also developed and then its usability was evaluated. The result of this study can be applied to the development of a pelvic airbag cushion system for absorbing falling impact energy.

## 5. References

- Fernandez, J.E., Ware, B.F., Marley, R.J., and Kumar, A.R (2011). Role of Physical Ergonomics in Litigation. *Ergonomics in Design: The Quarterly of Human Factors Applications*, 2011; 19: 4-8.
- Campbell, A.J., Borrie, M.J., and Spears, G.F.(1989), Risk factor for falls in a community-based prospective study of people 70 & older, *Journal of Gerontology*, 1989; 41: 112-117.
- Choi, K.W. and Lee, I.S. (2010). Fall Risk in Low-Income Elderly People in One Urban Area, *J Korean Acad Nurs*, 2010; 40(4): 589-598.
- Eom, J.Y. (2006). A study on the elderly patients hospitalized due to fall injuries, *Woman Health*, 2006; 7(2): 47-68A.
- Kang, K.H., Jeong, H.C., and Jeon, M.Y. (1999). A survey study on fall-related fractures in hospitalized elderly patient, *Journal of Keukdong College*, 1999; 251-264.
- Kim, J.M and Lee, M.S. (2007), Risk Factors for Falls in the Elderly Population in Korea: An Analysis of the Third Korea National Health and Nutrition Examination Survey data, *Journal of Korean Society for Health Education and Promotion*, 2007; 24(4): 22-39.
- Kim J.M. and Suh H.K. (2010). Risk factors for falls in the elderly by life-cycle, *Korean Journal of Health Education and Promotion*, 2010; 27: 21-34.
- Kim, W.O. (1998). The literature review for fall in the elderly, *The Korean Journal of Rehabilitation Nursing*, 1998; 1: 43-50.
- Korea Consumer Agency (2007). Old People's Safety, 2007.
- Mun, Y.H. (2005). The Prevalence and Associated Factors of the in-home Falls of the Elderly, *Journal of Korean Academy of Public Health Nursing*, 2005; 19(2): 249-260.
- Yoo, I.Y. and Lee, J.A. (2009). Characteristics and Factors Associated with Falls of the Community-dwelling Elderly in Small Cities, *J of Korean Society of Living Environment System*, 2009; 16(4): 428-435.