Studies on the Fall Patterns for the Development of a Fracture Prevention System

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Abstract: In recent years, the importance of the characterization of fall for a fracture prevention system keeps increasing since fracture from a fall can lead to serious health problems. Fall is one of the major sources which increase morbidity in elderly people. In terms of the cost and the influence to the quality of life, the most serious injury with hip fractures is caused by falls. The traditional methods in characterizing fall patterns have been mainly by the epidemiological surveys. With surveys, the exact data of fall patterns can not been acquired. In this paper, we measured and analyzed with the parameters related to fall pattern such as velocities and accelerations during the motion of falls using 3D motion capture program. We acquired the parameters of the fall pattern of intentional and unexpected fall. The result showed that the variation of velocity and acceleration during fall was very important in characterizing fall pattern, which of vital importance for the development of a fracture prevention system and for the safety of the elderly.

Keywords: Fall, Fracture, Fracture prevention

1. Introduction

The social activity of the aged has been increasing as our society progresses toward an aging society. At the same time, the falls due to the weakened physics and the reduced balancing capability of the aged are keep occurring. As a result, the occurrence of the fracture of bones will be increasing eventually. It has been reported that the occurrence of fall is about 25 to 30% among the ages over 60, 35% among the ages over 70, and 50% among the ages over 80 [1].

In United States alone, the number of the occurrence of hip fracture is more than three hundred thousands and the cost for the treatment is estimated to be about seven billion dollars.

As for the directions of falls, they are classified in three categories. They are forward direction, side direction, and rear direction. The most frequently reported fall is in forward direction with 58% of the total report. The next is in side direction with 30% and the last is in rear direction with 12%. When a fall in forward direction occurs, the probability of the occurrence of the fracture of arm and wrist is the highest. The facture at the shoulder or hip area is most probable when a fall occurs in side direction. As for the fall in the rear direction, lumbar fracture can occur most frequently.

The time for the recovery from bone fracture is clearly different for different age groups compared to other human organs. This is due to the fact that the bone density and the capability of cell regeneration of the aged are much lower than those of young people. Moreover, there have been number of reports on the deaths resulted from extended treatment time which caused reduction of body functions from limited physical activities[2]. The statistics show that the complications developed from a fall is one of the six major causes of the deaths of the aged. Therefore, to prevent such casualties from falls, a device that can prevent bone fracture by minimizing the impact and reducing damage from a fall is essential.

Here, we have analyzed the pattern of motion for falls occurring in different directions by using three-dimensional motion capture program to overcome the limitations in the previous analysis on falls, which is based on surveys. In addition, we quantified various parameters related to falls by accurately measuring and analyzing the velocity and the acceleration that occurred during falls so that the parameters can be utilized for the development of a fracture prevention system.

2. Theory of falls

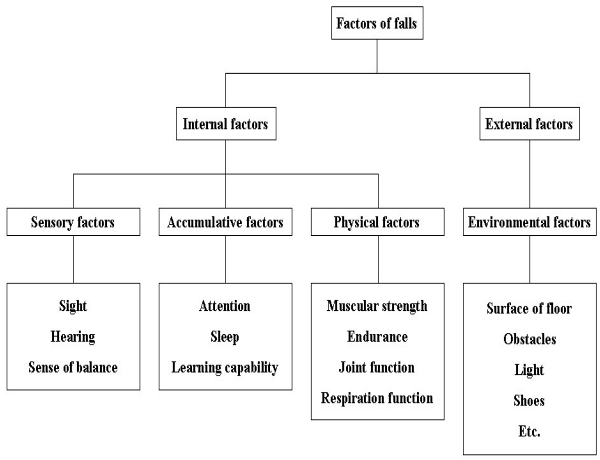

Fig. 1. Primary factors of falls

Figure 1 lists the major causes of falls. A fall can be defined to be unintentional contact of body to the ground [3]. It can occur from either internal factors or external factors [4]. To look closely into the two factors, the internal factors include sensory problems due to degraded ability of sight or hearing or loss of sense of balance, accumulative problems due to the lack of sleep or attention or the lowering of learning capability, and the problems related to physical capability due to the degradation of muscular strength, endurance, joint function, or respiration function. In the other hands, the external factors include environmental problems related to the surface condition of the floor, obstacles on the ground, or the lightening. However the cause of actual fall is a complex combination of all the factors.

3. Experimental Set Up and Methodology

Fall Measuring System

In the experiment, two kinds of falls were examined. One was an intentional fall which was initiated by the subjects themselves and the other was an unintentional fall which was initiated by experimenters. An unexpected fall was forced by pulling the mat on which a subject was standing [5]. In performing these experiments, the safety of the subjects was utmost priority. Therefore, a soft safety matt was used so that the impact of a fall can be minimized and the risk of fracture can be prevented.

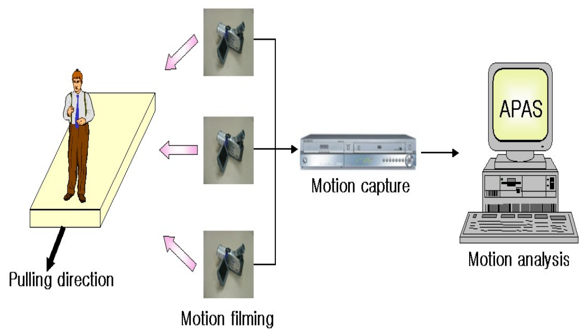

Fig. 2. Fall measuring system on the fall pattern

Figure 2 shows our fall measuring system consist of a three-dimensional motion analysis system called APAS(Ariel Performance Analysis System) by Ariel Dynamics. This system analyzes the motion of a fall based on the video footages captured by video cameras at different locations at the same time. At the first stage of the analysis, this system converts the video footages from the video cameras to a computer video file using a program called “Studio Version”. Next, only the necessary part of the file is trimmed out. The next step is that a program called “Digitizing”, analyzes coordinate pointers in the video footages and converts to the values in three dimensions. The last step is done by a pro-processor which can display graphs and various analysis data.

The system can obtain acceleration values in three-dimensions so that the absolute value is obtained with a three-dimensional vector unlike other systems which only give acceleration values in one axis.

Figure 3 shows the photos of a fall in the actual experiment in which three cameras recorded the motion. The experiment was done for (a) forward intentional falls, (b) rearward intentional falls, (c) forward unexpected falls, and (d) rearward unexpected falls.

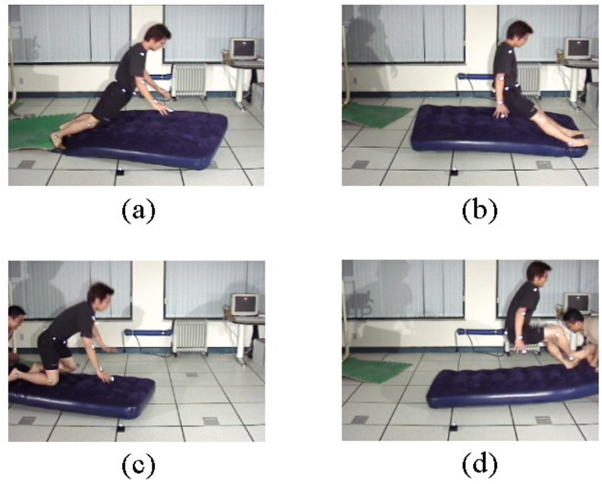

Fig. 3. Photo of fall experiments
(a) forward intentional falls, (b) rearward intentional falls, (c) forward unexpected falls, (d)rearward unexpected falls

4. Experimental Results

Forward Intentional Fall

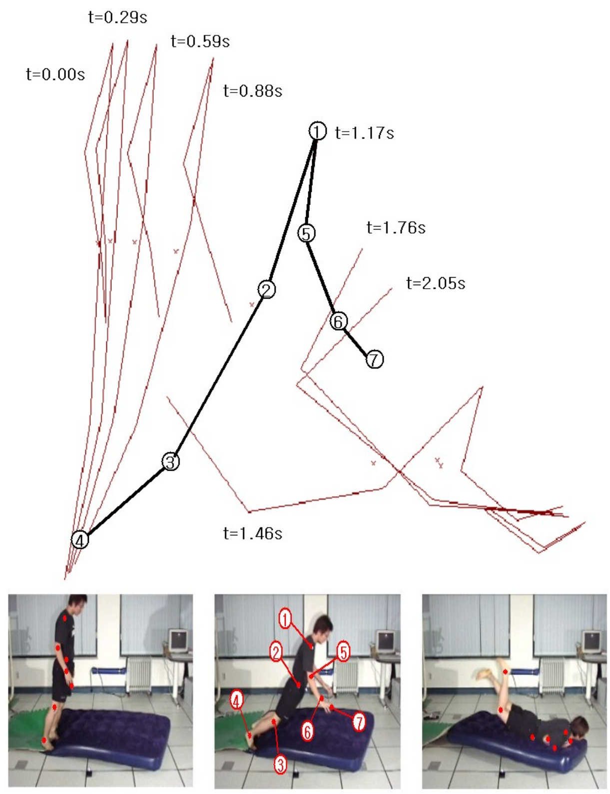

Fig. 4. Process of forward intentional fall on time

Figure 4 displays a process of forward intentional fall at different temporal stages. The patterns of fall was analyzed by seven targets attached on the subject’s body. The targets were rocated at seven parts of body such as shoulder, elbow, wrist, hand, hip, knee and foot. It shows that the motion of body was slow at first and the speed of motion was dramatically increased after one second. The reason why the motion of the body was slow at the initial stage seems to be that the fall was initiated voluntarily and the subject was hesitant in initiating a fall. The whole process of the fall took 2.05 seconds.

Figure 5 shows the absolute value of the acceleration of the targets mounted on the various places of the body of the subject. High acceleration values were observed frequently after 1.5 seconds. The value near the hip area suddenly changed to higher values right after 1.4 seconds. This is due to the contact between the hip and the ground.

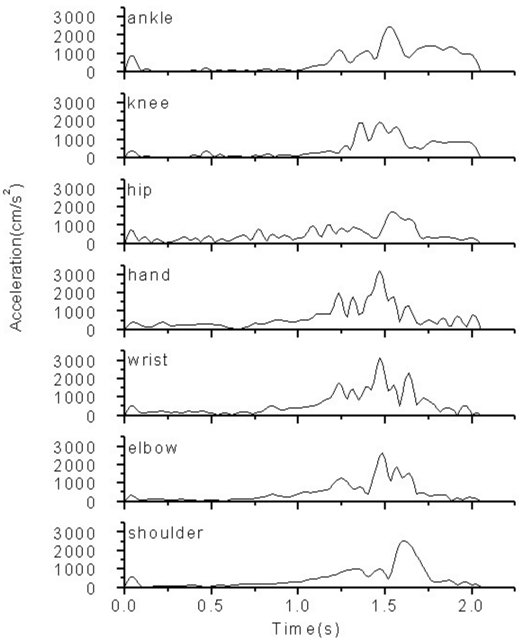

Fig. 5. Acceleration of whole target during forward intentional fall

Rearward Intentional Fall

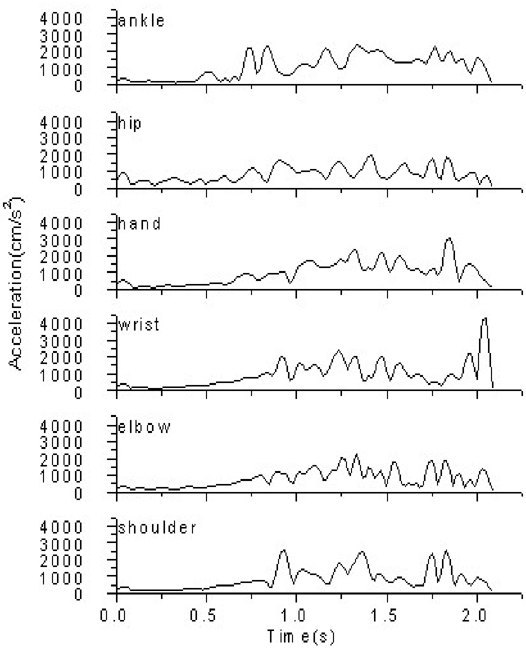

Fig. 6. Acceleration of whole target during reward intentional fall

Figure 6 shows the acceleration of the targets when a rearward fall occurred. Similar to the case with rearward intentional fall, the speed of motion increased after one second and the whole process of the fall took 2 seconds. The acceleration values observed at elbow, wrist, and hand area were similar to each other once the speed of motion increased after one second.

Forward Unexpected Fall

In the previous cases with intentional falls, there were limitations in obtaining parameters that correlate to realistic falls since the subject tended to be hesitant in initiating falls fearing the impact from falls and worrying about injuries. Therefore, a way to initiate more realistic fall was improvised. An unexpected fall was forced by pulling the mat on which the subject was standing without warning or hint by the experimenter.

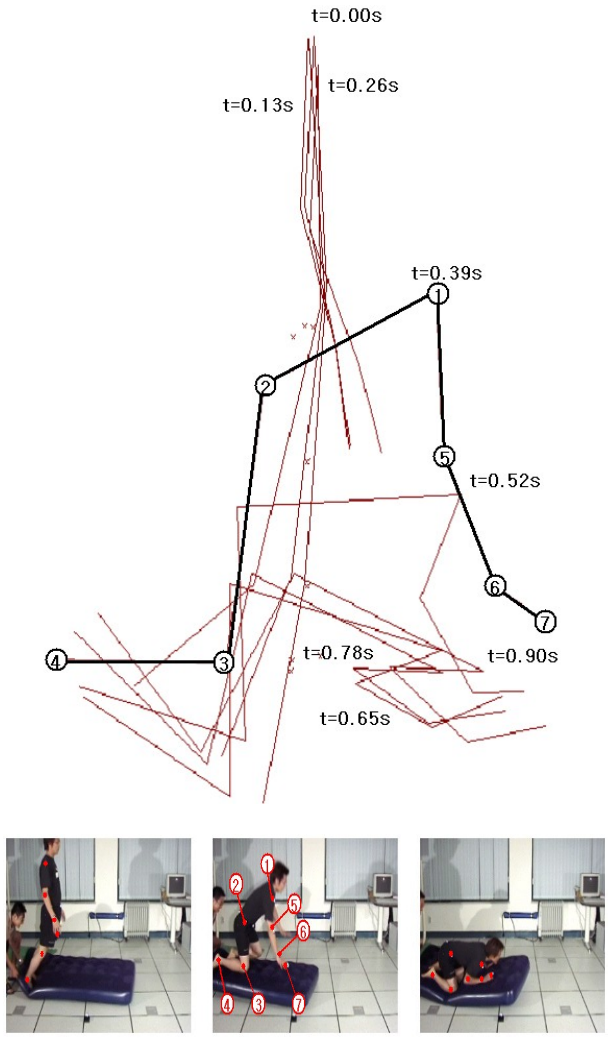

Fig. 7. Process of forward unexpected fall on time

Figure 7 shows the process of a forced forward fall at different temporal stages. Unlike the cases with intentional falls, the whole process of the fall took less than 1 second.

Figure 8 shows the acceleration of the targets when a forward forced fall was occurring. The acceleration increased right after 0.2 second and it reached 4000 cm/s^2 at 0.4 second when the speed dropped suddenly. The high acceleration was observed at 0.8 second when the velocity of the wrist and the hand changed suddenly.

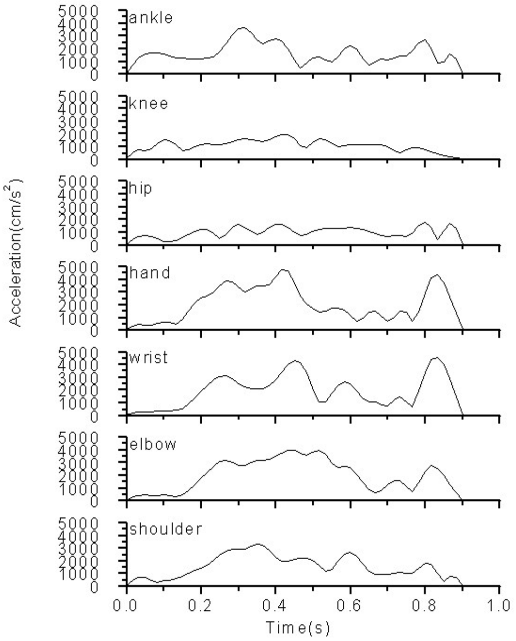

Fig. 8. Acceleration of whole target during forward unexpected fall

Rearward Unexpected Fall

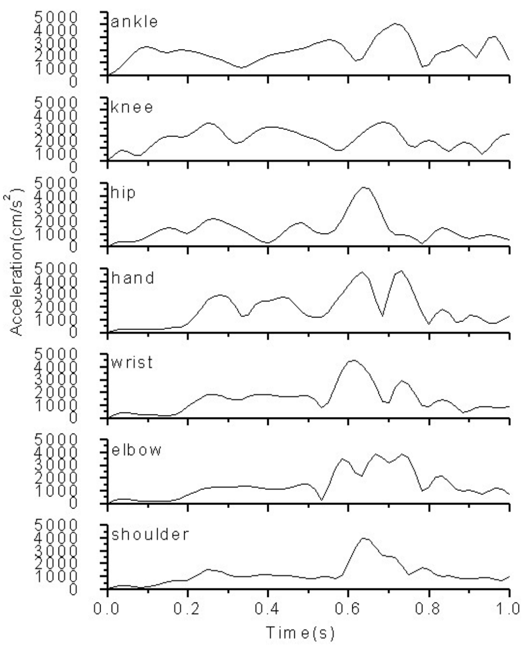

Fig. 9. Acceleration of whole target during forward unexpected fall

Figure 9 shows the acceleration of the targets when a rearward forced fall was occurring. The whole process of the fall took 0.9 second, which is similar to that of the forward forced fall. The high acceleration value observed at ankle area in the initial stage like in the forward forced fall case was due to the pulling of the matt by the experimenter. The average acceleration at the initial stage was about 3000 cm/s^2 and it increased to 5000 cm/s^2 at 0.6 second when the body started to descend. The acceleration at the waist area was also about 48000 cm/s^2 at 0.6 second.

5. Conclusion

In this study, we tried to accurately measure and analyze the acceleration of body when a fall, the main cause of the fracture of the elders, occurs. For this purpose, we used three-dimensional motion analyzer and found the following points.

1. The maximum acceleration observed during a fall was at least 2000cm/s^2 which is higher than the maximum acceleration of 1500cm/s^2 observed during regular activities.
2. We were able to distinguish different motion patterns for different kinds of falls by analyzing falls in different directions. This data will be the basis in detection and identification of whether a fall is occurring and what kind of fall is occurring. Thus, this work will be used for our ongoing study on the development of a fracture prevention system.

Acknowledgments

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