

# Case Study on Possible Falling Patterns of a Fatal Fall from Stairs

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**Abstract:** Considering a fatal case of an aged individual, who died due to falling down stairs, the cause of the fatal fall was investigated through experiments. A witness, who was with the victim, when the fatal accident occurred, stated that the aged individual had miss-footed, lost balance at the top of the stairs, and fell accidentally from an upper floor to a lower floor. It was very questionable whether or not this witness's statements were true. The true cause of the fatal fall was unclear, because of the witness's inconsistent statements, which showed discrepancies between the initial and later statements. The cause of a fatal fall can be presumed from external and internal damages to the body and other circumstantial evidences. But it was difficult to prove the true cause of a fatal fall only from the results of the autopsy and investigation of circumstantial evidences. The author was officially requested to conduct experiments to elucidate possible falling patterns. Judging from the experimental results, deep questions about the witness's statements arose. These experimental methods and analyses in this paper could be applied to elucidate possible falling patterns of fatal falls from stairs where the fatal causes are controversial.

**Key words:** Stairs, Fatal fall, Accident, Backward fall, Head impact, Forensic analysis, Ergonomics

## Introduction

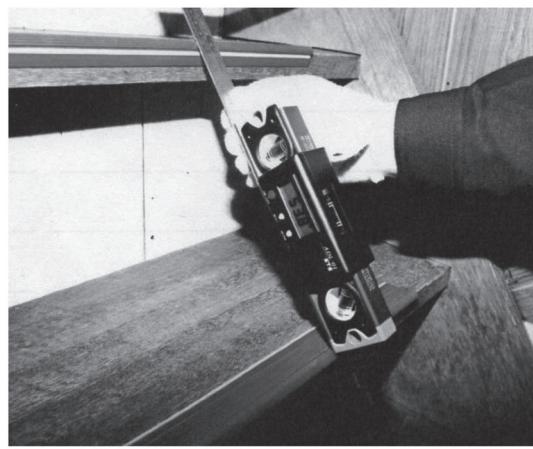
According to the mortality statistics classified by the International Classification of Diseases recommended by the WHO-World Health Organization, 1,917 deaths due to falls on/from stairs and steps in the United States in 2007<sup>1)</sup>, 693 deaths in England and Wales in 2011<sup>2)</sup>, and 679 deaths in Japan in 2012<sup>3)</sup>. Many researchers have undertaken demographic or epidemiological surveys for stair related injuries<sup>4–7)</sup>. As far as the author surveyed past literatures, an experimental article for a fatal fall based on the autopsy results and detailed configurations of stairs, where a fatal fall occurred, was not found in past research

papers. Most fatal falls from stairs are caused by serious head injuries<sup>5, 6, 8)</sup>. Whenever a fatal stair-accident occurs, the actual duration time until receiving the first impact by falling down the stairs is within a second, according to the author's experiments<sup>9, 10)</sup>. Because of the instantaneous occurrence of a stair fall, it is very difficult to find a witness who sees the entire falling patterns down stairs.

In the case of no witnesses, the cause of a fatal fall can be sometimes determined from external injuries on the corpse and circumstantial evidence. Computer simulation can be used to determine the possible falling patterns, nevertheless, these simulated results are likely to be largely influenced by initial input parameters, and are not always reliable to identify the specific decisive causes of actual fatal falls. Taking one fatal case of an aged individual, who died of severe head injuries, due to a fall down the stairs at a residential home, the cause of that fatal fall was investigated. Only one witness was with the victim when



(a) View from the upper stairs



(b) Incline of the stairs

Fig. 1. Survey of the actual stairs. (a) View from the upper stairs (b) Incline of the stairs.

the fatal accident occurred. It was questionable whether or not the witness's comments were true. The fatal fall was examined using a dummy and experimental stairs with the same configurations, such as the dimensions of the tread rise etc. From the analyses of the experimental falls by a dummy from stairs, serious questions about the witness's statements arose.

## Conditions of the Fatal Fall

### *Statements by people specifically involved in this investigation*

It was reported that one aged individual fell from the top of the stairs at victim's home. According to the initial on-site statements of the witness, the aged victim had accidentally miss-footed, lost balance at the top of the stairs, and fell from an upper to a lower floor. But strong doubts arose from statements by the rescue crew members. They found broken debris scattered around the top of the stairs just after arrival at the victim's home. When they questioned as to what happened, the witness confessed to have had a quarrel with the victim at the upper floor near the entrance to the stairs. The witness implied that witness slightly pushed the aged victim just before the occurrence of fall-incident in witness's first comments. Judging from the suspicious circumstantial appearances, the rescue crew members speculated that some sort of skirmish had occurred and about the possibilities of violent action such as shoving the victim near the upper stairs might have occurred. They reported this information to the regional police office. Several policemen soon came and questioned the witness on-site. They suspected the

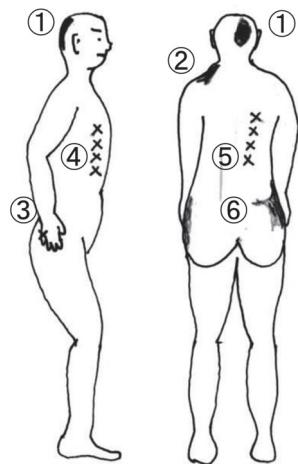
witness's explanation because of inconsistent statements and indications that the aged victim was shoved at the top of stairs. After retaining attorneys, the suspect stated that the victim fell down from the top of the stairs accidentally and completely denied the initial statements that the witness gave external forces to the aged victim, and exercised one's own constitutional right to remain silent during the public prosecutors' interrogations. The public prosecutors were undermined as to the true cause of the fatal fall.

### *Physical conditions*

Based on a detailed search warrant of the actual stairs, an inspection was conducted by public inspectors, police officers and the author as shown in Fig. 1. The wooden stairs were 177 cm long and 264 cm high. The stairs with width of 90 cm consisted of 12 steps with a tread of 16.6 cm and a rise of 22.0 cm except for the top step, which had a tread of 23.0 cm and a rise of 25.0 cm with non-slip vinyl edge of the step. The incline of stairs was 53 degrees except for the top part of the stairs which was 47 degrees. A handrail was installed at one side wall of stairs with the height of around 70 cm from the step edge. The heights from the landing of the 1st floor to the overhang above stairs was 207 cm.

### *Autopsy of the victim*

The victim died two days after the fall. According to the results of the autopsy, the occipital area of the head and the top of the left shoulder bones were severely fractured, and the author illustrated outline drawings from the detailed results of autopsy as shown in Fig. 2. A clear ellipse-shaped impact blow mark could be seen on the oc-



**Fig. 2. External injuries.**

- ① Severe impact blow marks on the occipital area of the head with skull fractures, ② Severe impact blow marks with fracture of left upper shoulder, ③ Fracture to the left little finger, ④ Fractures of right frontal rim bones, ⑤ Fractures of right back rim bones, ⑥ Bruise marks on lumber area.



**Fig. 3. Dummy.**



**Fig. 4. Model clay head.**

capital area of the head, and bruises at the right backward side of lumber areas were observed. It was apparent that the victim fell backward from stairs and the occipital area of the head was strongly impacted on a solid flat surface. The major fatal causes of death were by the fracture of the skull and intracranial injuries. Several rib bones could have broken while giving manual resuscitation. But it was inconceivable that ellipse-shaped reddish congestions in the upper front part of the left breast would be observed, if the victim fell backwards from the stairs.

## Methods

### Falling patterns

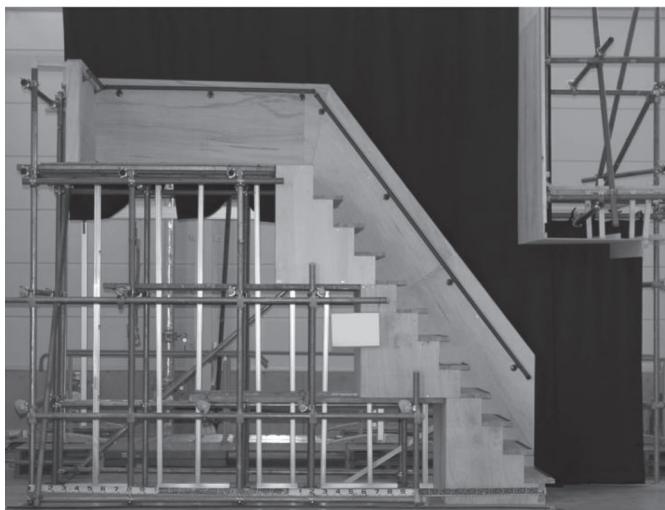
According to the author's previous investigations of the actual backward fall experiments from stairs<sup>9)</sup> and by using a dummy on the level surface<sup>10)</sup>, it was observed that the first impact to the back of the head caused the most crucial injury within a second, as it kept rolling down to the lower floor. In these experiments, the focus was placed on the head impact blows just after the backward fall. These actual falling patterns were examined to determine the possible falling patterns to cause such fatal head injuries. Various possible falling patterns were analyzed in case of a natural fall and intentional falls. Each falling pattern was recorded by a high speed camera at the rate of 240fps (Type: Casio EX-FH25). Each of the following

three major experiments were conducted once.

1. Natural fall assuming an unintentional fall
  - A backward facing dummy was supported in an upright posture at the end of top of stairs, and was leaned backward at a very slow speed until it fell naturally by itself without external forces.
2. Intentional fall assuming a fall from shoving at a standing-still posture
  - A backward facing standing dummy was intensively shoved by an adult at the end of top of stairs.
3. Intentional fall assuming a fall from shoving during a stepping-back posture
  - A backward standing dummy on a thin wheeled platform was moved at the speed of 1.6 km/h, and was intensively shoved by an adult at the end of top of stairs.

### A dummy and mock-up of the stairs

To extrapolate the possible falling patterns of the victim from stairs, a dummy, and model of a head and mock-up stairs with the similar configuration of the actual stairs were prepared. The dummy's weight was 64 kg, and the height was 150 cm, approximately the same weight and dimensional configurations of the victim as shown in Fig. 3. The major structure of the dummy was steel cov-



(a) View from the anterior side of stairs



(b) View from the top of stairs

Fig. 5. Mock-up of the stairs.

(a) View from the anterior side of stairs, (b) View from the top of stairs

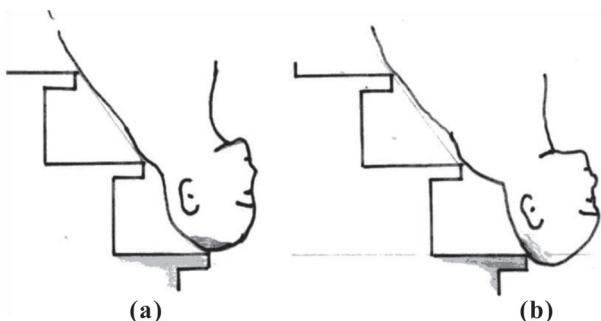


Fig. 6. Predicted injuries to the head on the tread and the step edge.

(a) Planar injuries at the parietal area of the back of head,  
(b) Linear injuries in the occipital area of the head

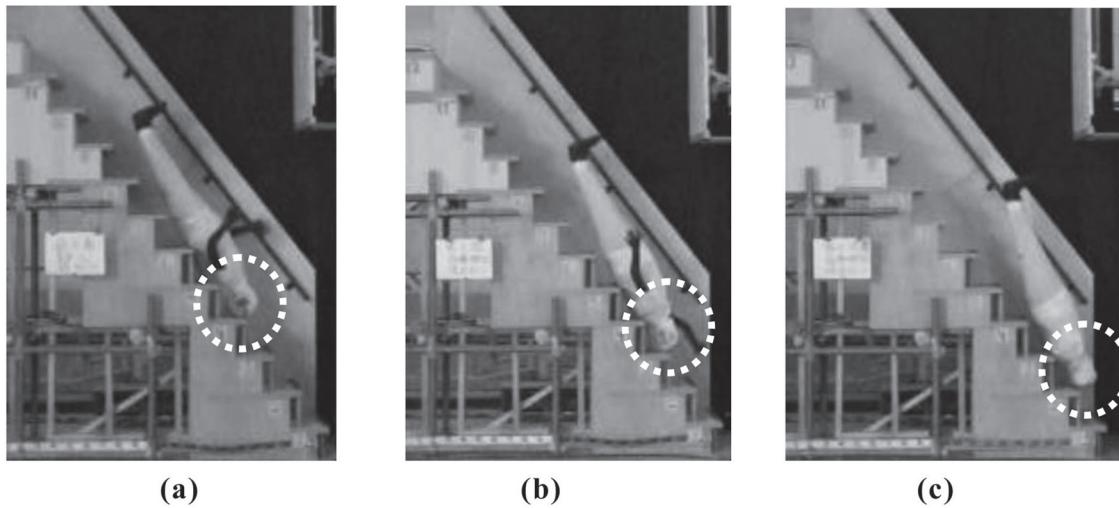
Fig. 7. Damage observed on the parietal area of the dummy in the case of impact on the tread.

ered with urethane. Consequently, each arthro of a dummy was immobilized except for the shoulder joints. The center of gravity of each limb and the whole body weight were adjusted by the insertion of lead or iron inside the dummy. A model clay head with the similar dimensional configurations as the victims was made as shown in Fig. 4. This model clay head was used to search for the impact point determined from actual steep dimensional configurations of tread and rise prior to conducting the experiments. Mock-up stairs were made of wooden materials supported by steel scaffoldings as shown in Fig. 5.

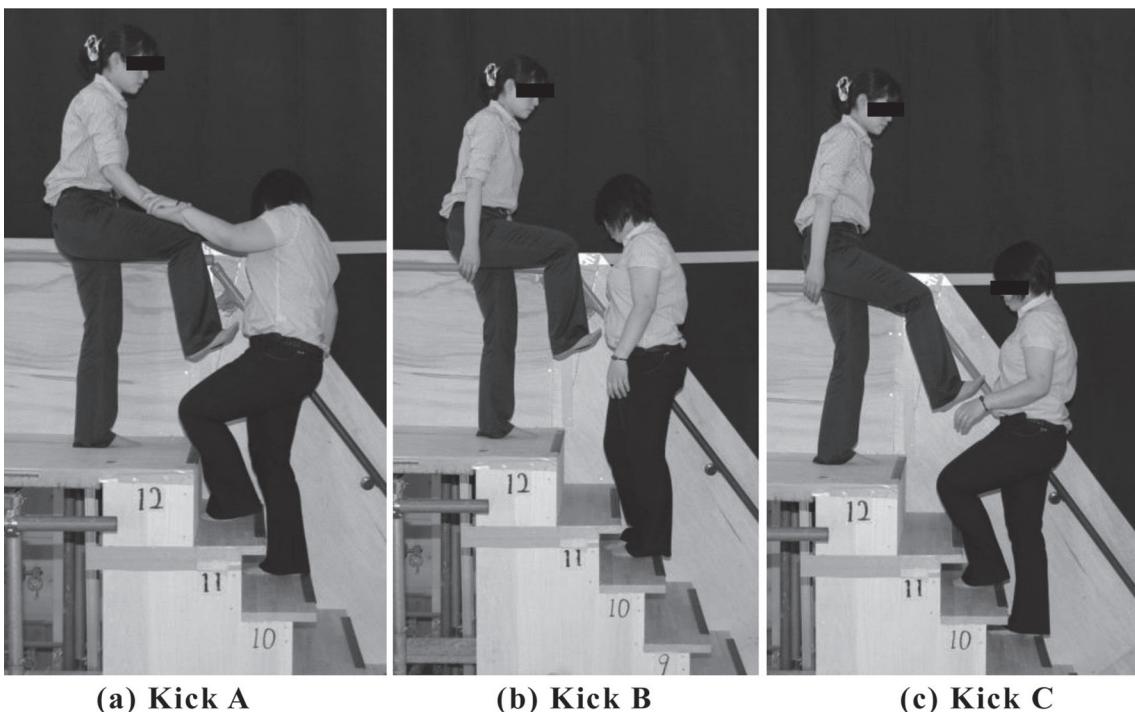
## Analyses and Results

### *Analysis of external injuries*

A model clay head with the similar dimensions to the victim's head was utilized to check the damage points of injuries on the step. Assuming that the first blow impact to the back of the head occurred on the tread surface or at the step edge, traced marks of external injuries on the back of the head were observed such as planar injuries at the parietal area of the head as shown in Fig. 6a or linear injuries in the occipital area of the head as shown in Fig. 6b. A dummy, whose head was covered with paper coated with pressure sensitive red-dye, was shoved over the step. Red scars were observed at the parietal area of the head as



**Fig. 8.** The first impact points to the head on the steps.  
(a) Natural fall, (b) Shoving a standing dummy, (c) Shoving a moving dummy.



**Fig. 9.** Possible falling patterns from intentional kicks.

shown in Fig. 7. Actual fatal impact injuries of the victim formed an ellipse-shaped blow mark in the occipital area of the head.

#### *Analysis of falling pattern*

The dummy's head impacted on the fourth step from the lower landing in case of natural fall without any external forces as shown in Fig. 8a. The dummy's head

impacted on the third step from the lower landing, in case of external force toward standing still posture as shown in Fig. 8b. The dummy's head impacted on the second step from the lower landing, in case of shoving a moving dummy at the constant speed of 1.6 km/h as shown in Fig. 8c. According to every result of experimental falls using a dummy, the dummy hit its head on the step in every experiment. The aged victim fell backwards and was clear

that the occipital area of the head intensively impacted on the flat surface, such as the lower landing, judging from evidence of the autopsy, which showed the ellipse-shaped injuries on the occipital area of the head. Analyzing these results of experiments even in the intentional case of shoving it with moving backwards, the back of the head of the dummy did not impact on the lower landing, but on the tread surface.

## Discussion

From the experiments and autopsy, it was apparent that the fatal victim fell backwards and struck the occipital area of the victim's head not on the step, but on a flat surface such as the lower flat landing, and that the victim was shoved from the top of stairs by intensive external force in the case of the fatal fall initiated around the top of the stairs. Judging from ellipse-shaped reddish congestions in the upper front part of the left breast were observed by the results of the autopsy, another criminal scenario can be considered to give intensive external forces to the victim, while beginning to descend a few steps below from the top of stairs. These speculations pointed out the fact that the upper left breast of victim was kicked strongly as shown in Fig. 9. It seems to be difficult to kick strongly on the upper breast on the first and second step as shown in Fig. 9a. The suspect could kick the victim's upper breast strongly on the left breast by a right foot, presumably when the victim was standing on the second or third step from the top of stairs as shown in Fig. 9b or 9c. The victim would likely fall and impact directly near the lower landing, and hit the occipital area of victim's head severely as shown in Fig. 10.

## Conclusion

Form the experimental results, it is very unnatural that the occipital area of the head of the fatal victim was strongly impacted on the flat surface like a lower landing without an external stronger force. The ellipse-shaped reddish contusions on the upper front part of the left breast were considered to be caused not by drop impacts, but by an intentionally strong kick. The only witness stated that the victim fell down from the top of the stairs without any external forces. According to the experimental analyses of actual falls of a dummy from stairs and observations of fatal head injuries, it is very suspicious that the victim had accidentally missteps, lost balance at the top of the stairs, and fell from an upper to a lower floor. These experimen-



**Fig. 10. Possible head impact on the lower landing.**

tal methods and analyses could be applied to elucidate possible falling patterns of fatal falls from stairs where the fatal causes are controversial.

## Acknowledgements

The forensic and experimental investigation, which was reported to the district court, were experimentally conducted based on an official request to the author by the Regional Public Prosecutor's Office. I would like to acknowledge the Public Prosecutor's Office agreement in presenting the experimental results and scientific analyses of the fatal fall from residential stairs on the condition that the victim can not be identified from the data in this paper.

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