Forensic Science International 244 (2014) 136–151

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Fall from height in a stairwell – mechanics and simulation analysis

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ARTICLE INFO

Article history:
Received 15 May 2014
Received in revised form 25 July 2014
Accepted 19 August 2014
Available online 29 August 2014

Keywords:
Fall from height
Biomechanics
Simulation

ABSTRACT

The range of problems considered in the biomechanical analysis of a fall from height has been presented. A complicated case of a fall in a stairwell was investigated, the analysis of which demonstrates the research scale and aspect multitude. The scope of the article was restricted to the analysis of biomechanical problems and the simulation analysis of the event. A virtual 3D model of the stairwell was built using sketches, photographs and photogrammetric techniques. A dummy created according to the victim's data was parameterised. Using the PC-Crash biomechanical module a series of several hundred simulations were run following the adopted research plan, allowing for pre-formulated boundary conditions. The region of the stairwell where the accident was likely to originate and the victim's initial configuration were identified. It was proved that biomechanical simulation can bring invaluable benefits in exposing the mechanism of an event and verification of various hypotheses. Despite general similarities, each fall has its own specificity, which, making the use of methodological generalisations difficult, increases the significance of casuistry. The presented analysis can prove very useful in providing guidelines on investigating other cases.

1. Introduction

The literature on falls from height is extensive but its application in the analysis of actual cases poses some problems because the majority of works is focused either on casuistry or presentation of statistical data presentation which are not directly applicable in individual cases. Scientific information on the biomechanics and simulation of such events is relatively inadequate in quantity particularly in the field of forensic science [1–9], where simulation techniques are most frequently used in the analysis of a single, narrow aspect of the event. With these deficiencies in mind an attempt has been made to perform biomechanical simulation tests that could significantly extend the knowledge of the event.

The needs of forensic science in events of this type are specific because they relate to several overlapping areas of knowledge: forensic science, mechanics, biomechanics and forensic medicine. In each individual case it is difficult to even decide which is the key one. Sometimes, when an unambiguous answer to the questions posed by investigating organs cannot be found, an incomplete description of the event is produced using partial answers, including arguments for and against together with hypotheses filling the gaps. The questions asked by the prosecution or court are aimed at the reconstruction of a given event rather than obtaining general statistical knowledge of similar events.

In the case of a fall from height there are always wide groups of factors to be considered, verifiable in the sense of confirmation, exclusion or likelihood of their effect on the event. The crucial ones include:

(a) Height of the fall.
(b) Type of ground on the fall site.
(c) Body position at the moment of first contact with the final surface.
(d) State of consciousness and defensive reactions (intermediate contacts with elements on the fall trajectory).
(e) Victim's age and mass of body.
(f) Course of the falling.

Since the basic task of an expert from the point of view of the administration of justice is most frequently to verify the likely cause of fall initiation, the number of hypotheses should be limited to the maximum by rejecting unreal cases.

Apart from involuntary (an unfortunate accident, stumble) or suicidal causes deliberate actions by a third party occur (pushing, throwing out), which additionally can be preceded by a physical

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http://dx.doi.org/10.1016/j.forsciint.2014.08.018
0379-0738/

assault on the victim (beating, torture). In the latter cases apart from identifying the cause of the fall it is equally important to separate the injuries suffered in the fall from any potential injuries inflicted previously.

2. Description of event

On the stone floor of the stairwell of a mediaeval house the dead body of a man was found. The body was lying on its left side, with the face towards the ground, along the eastern wall of the stairs. The arms were positioned along the body: the left arm under the trunk, the right one on top of the trunk and slightly left backwards, legs outstretched, slightly spread. The event was investigated by the authors of the present article many years after the accident, when the stairwell had been rebuilt substantially, which made the photographic documentation extremely important. Due to the perspective of the photographs they were subjected to photogrammetric transformation in PC-Rect program [10,11], determining the real position of the body relative to the elements of the stairwell such as the walls, stairs and balustrades. There had been strong suspicion that a third party was involved in causing the death, although the medical analysis definitely proved that the injuries had resulted mainly from the fall from a height.

Due to the historical and political context of the case and constantly recurring doubts about the findings (did the victim indeed fall from a height; if so, in what circumstances; was he first beaten and later planted at the staircase?), it was decided to extend the medical examination of biomechanical aspect, taking into account the progress that has been made in the past few decades in this area.

3. A virtual model of the stairwell

The 3D model of the object was made in PC-Crash program (which was later used in the simulation of the fall, see Section 7.1), meticulously reconstructing all the steps, treads and risers, landings, newel posts, balusters, handrails, stringers from the ground floor to the 4th floor, walls, doors, windows, stairs leading to the attic, the passage from the front door to the hall, ceiling arches above the ground floor, the wooden post between the 1st and 2nd floors. Fig. 1 shows the virtual photograph of the computer model, made with wide-angle lens, the complete model of the hall as views directed at the walls has been shown in Fig. 2.

4. Analysis of facts

The following symbols have been used to indicate the walls: E – eastern, N – northern, W – western, S – southern.

Fig. 1. Virtual photograph presenting the computer model of the object.

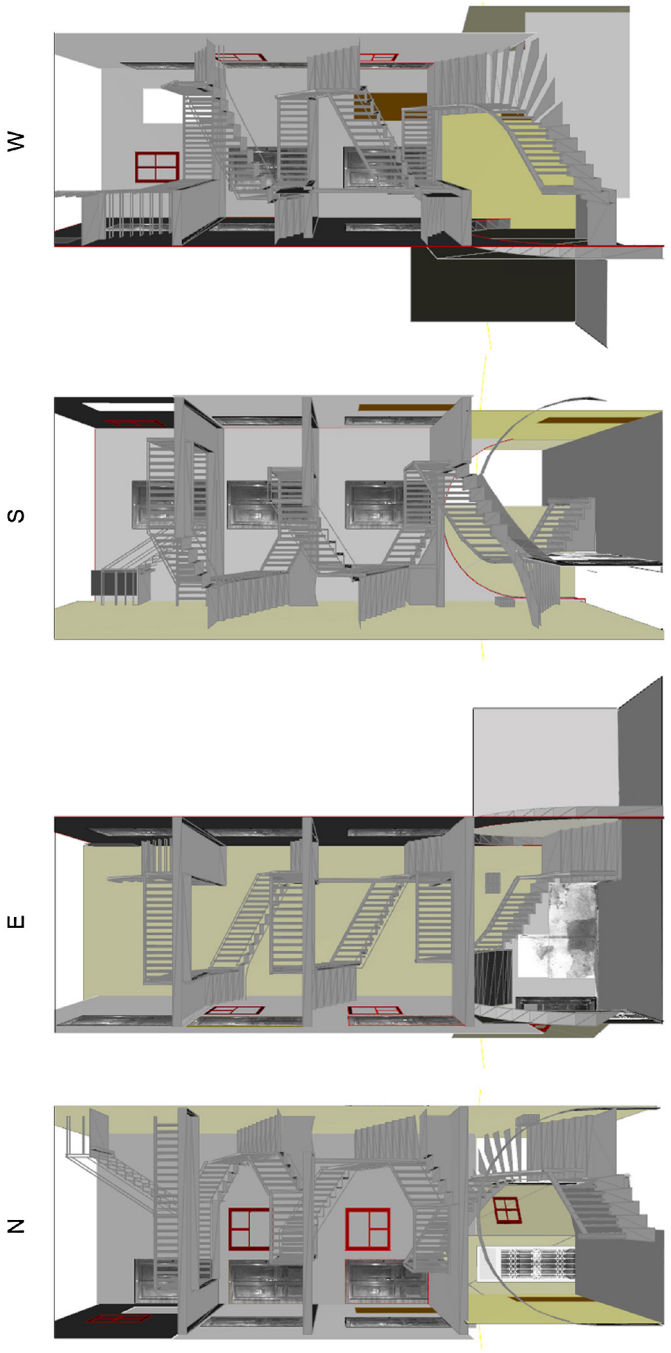

Fig. 2. Particular walls of the hall in central projection.

The 3D model of the hall made it possible to identify very precisely the position of the body relative to the stairwell: in Fig. 3 it was shown in central projection, in Fig. 4 bird's eye orthogonal projection. As can be seen, the upper part of the body was located under the overhang created by the northern flight of stairs from the ground floor to the 1st floor, while the lower part was in the empty inner space of the hall.

In the lower part of the hall the flight of stairs on wall E leading to the 1st floor was connected with the flight of stairs on wall N by the kite winder at turns. On the upper floors the stair runs were connected on quarter space landings. The steps from the ground floor to the 1st floor (red number 1 in Fig. 3) from E and N sides were wider than the steps from the 1st floor to the 2nd (2), and these were wider than the steps leading to the 3rd floor (3), which is best seen in the orthogonal projection in Fig. 4.